Interannual variability of the ocean surface circulation in the Japan/East Sea

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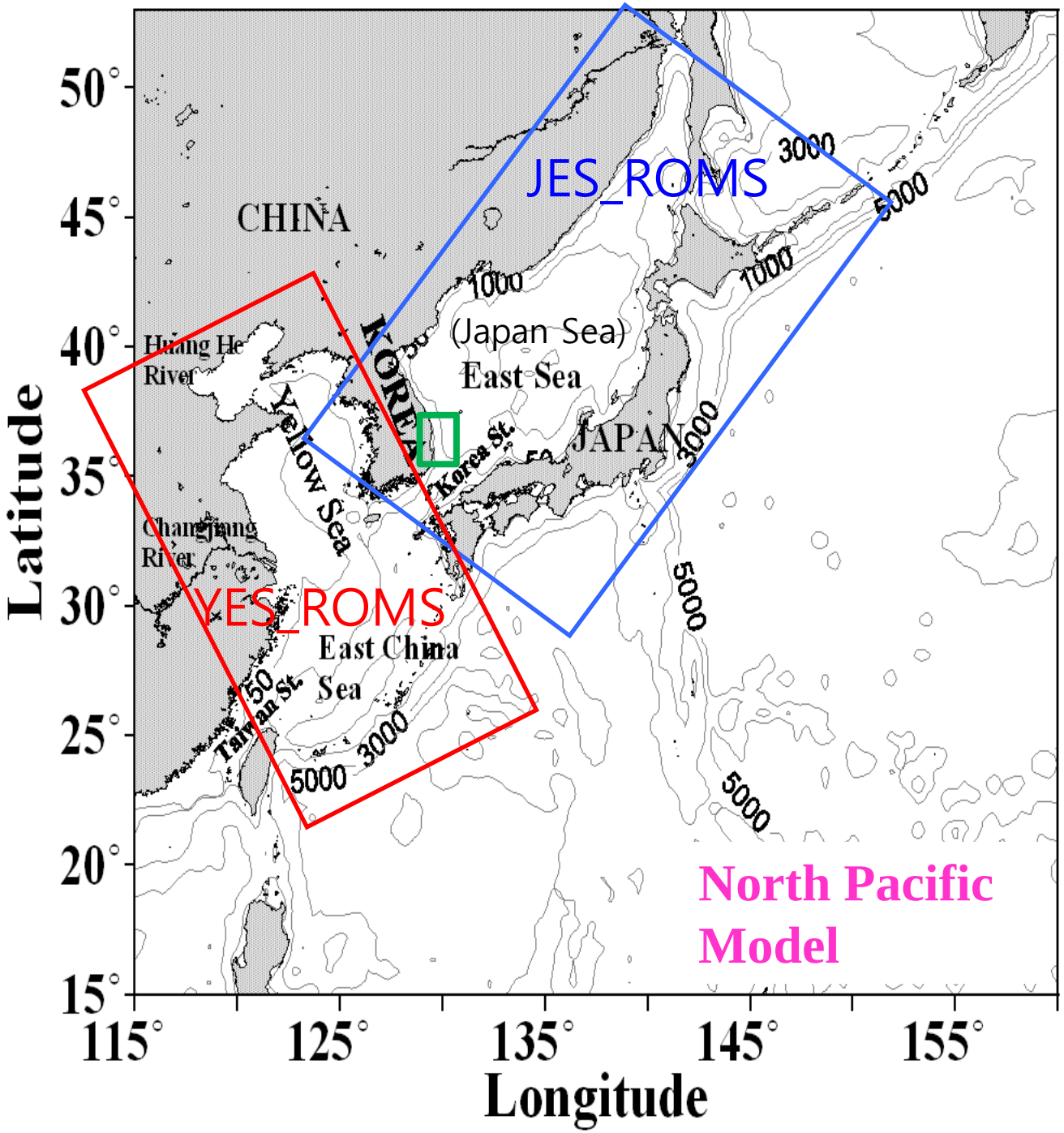
COSS-ICW3
21-24 January 2014

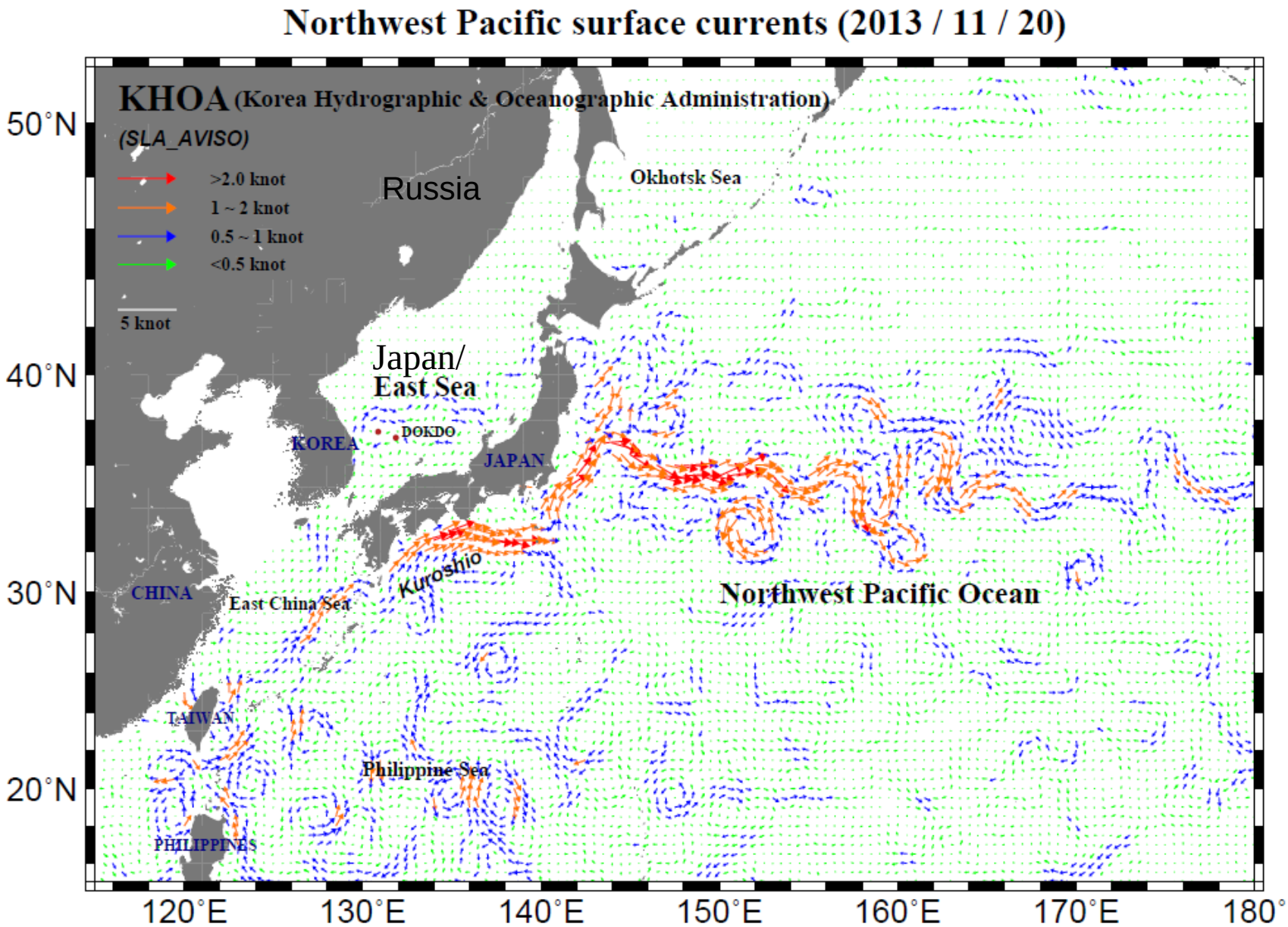
Regional and coastal ocean forecasting system in Korea



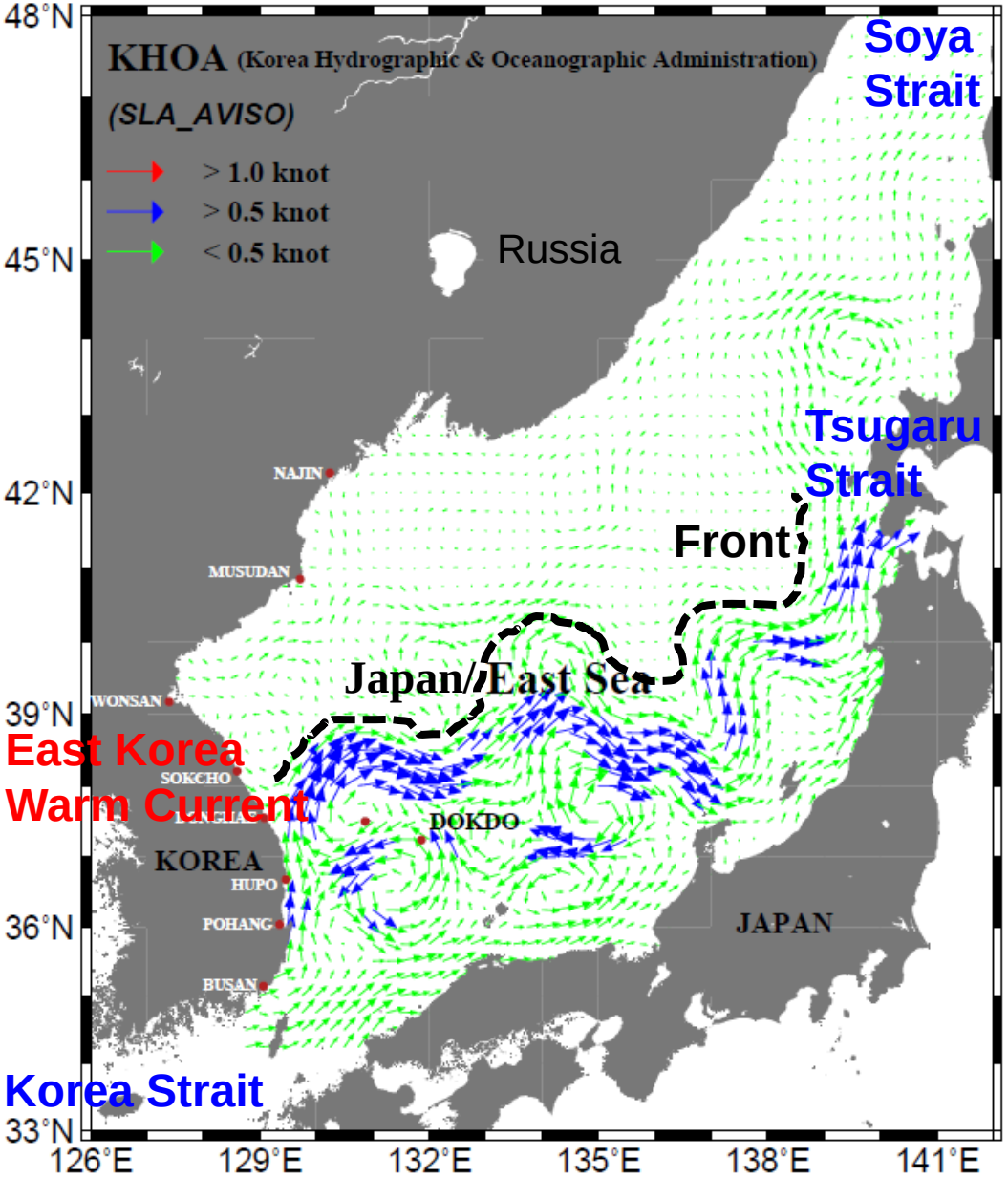
Korea Hydrographic and Oceanographic Administration (KHOA)

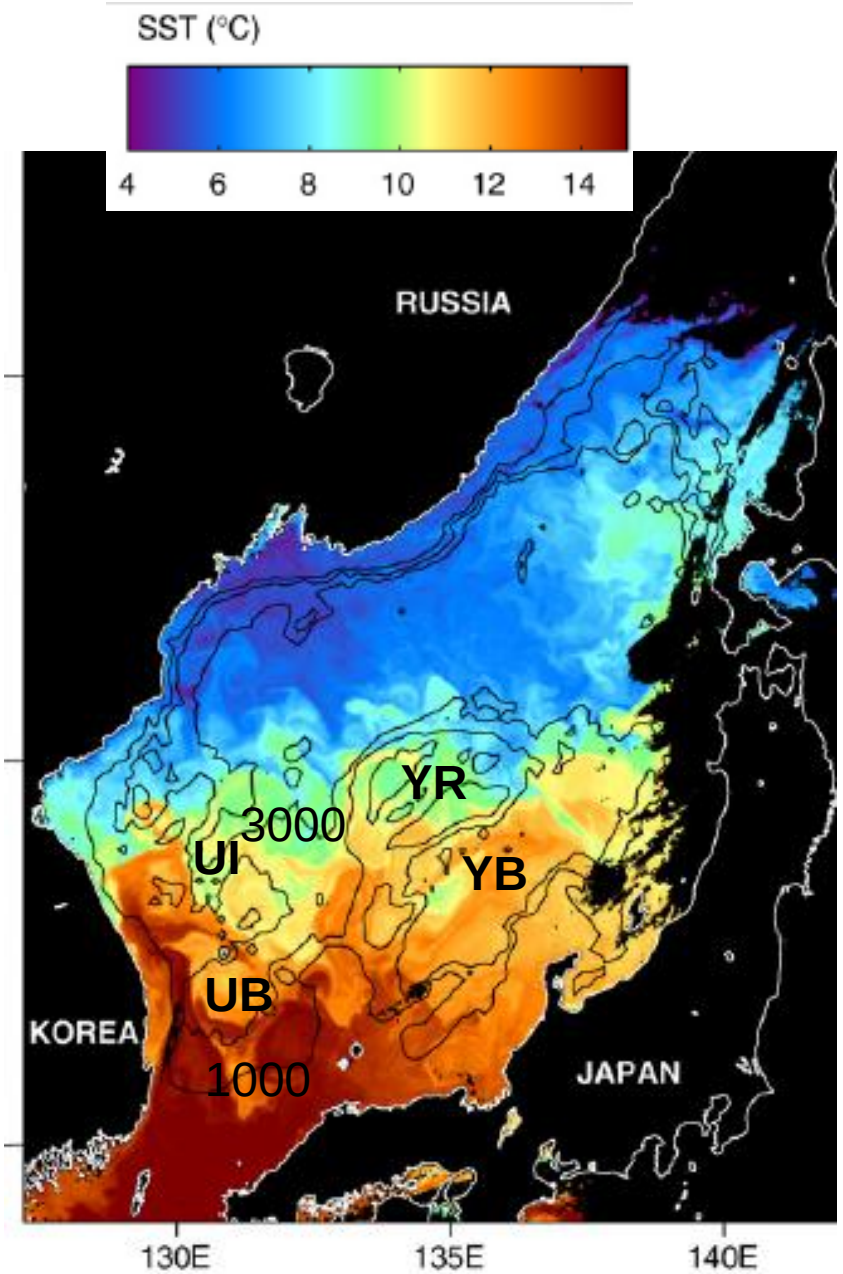
Contents

1.1 Background

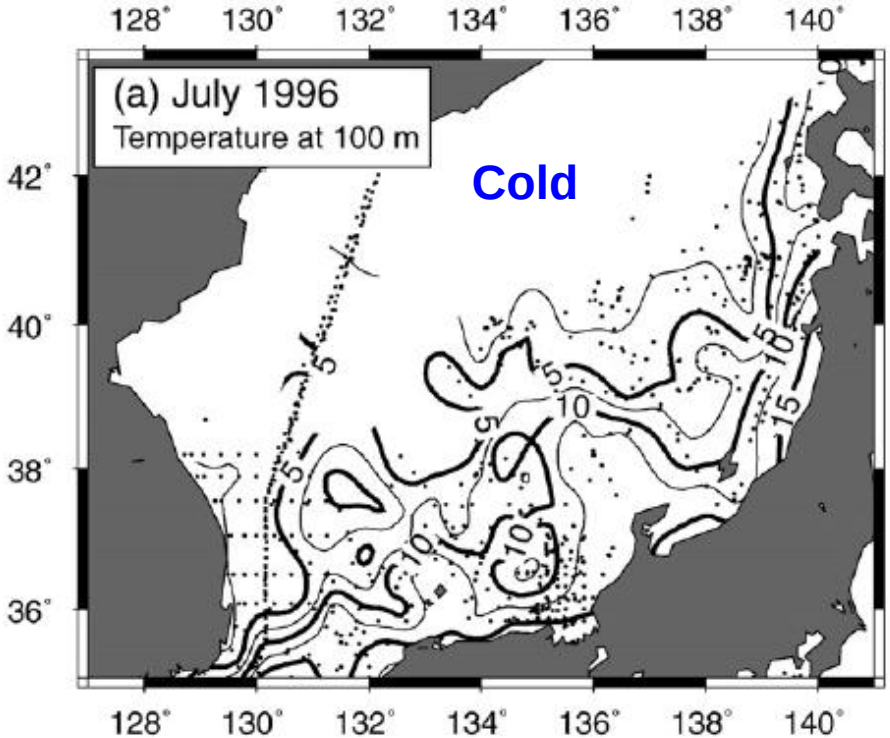


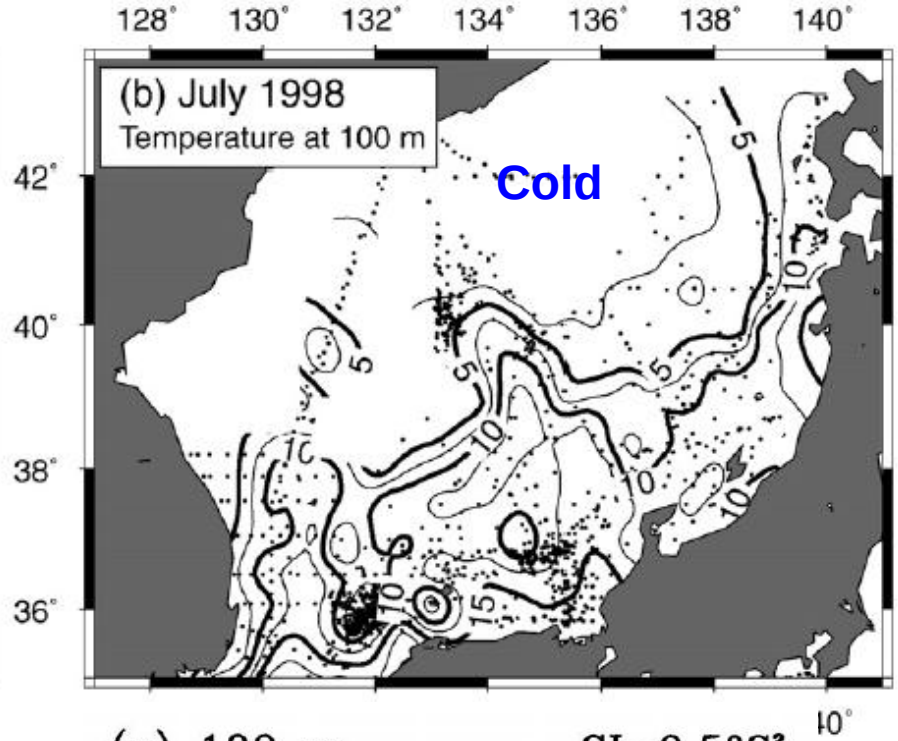
Japan/East Sea surface currents (2013 / 11 / 20)



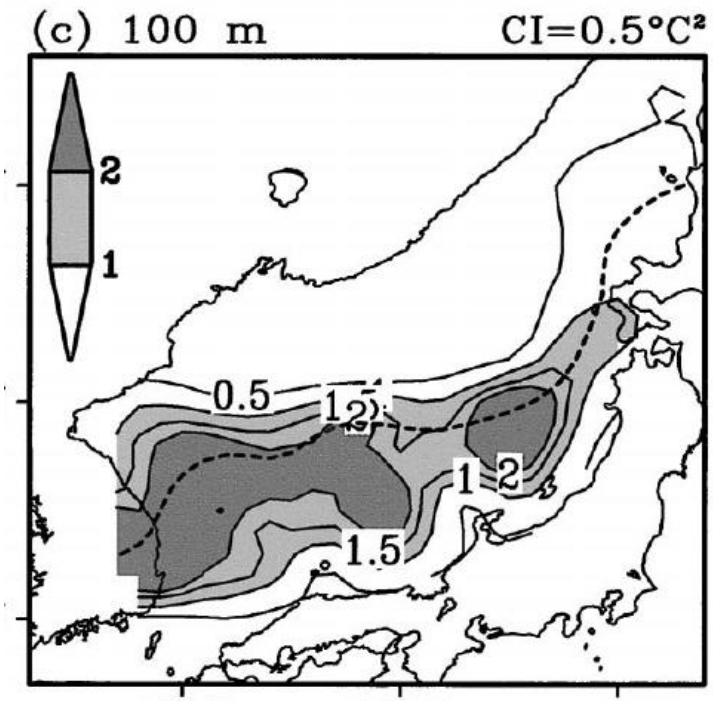


May 5, 1991 (Park et al., 2007)

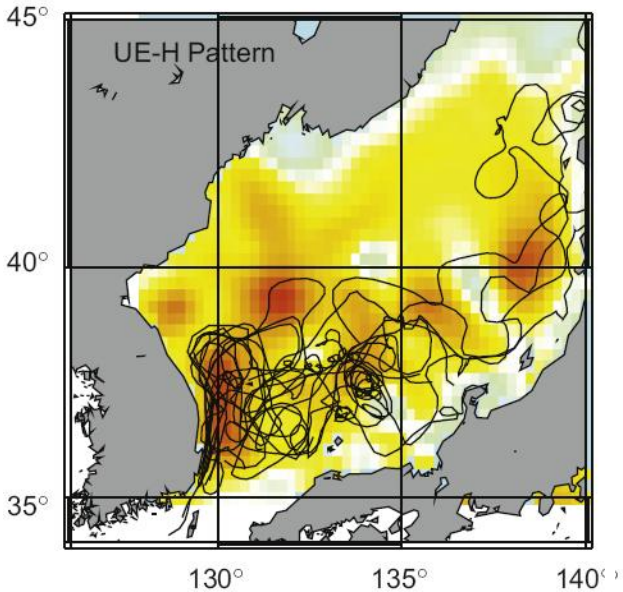


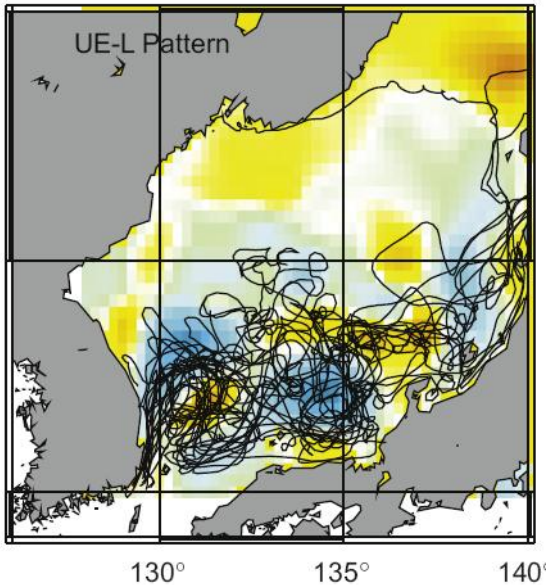


Choi et al. (2009)

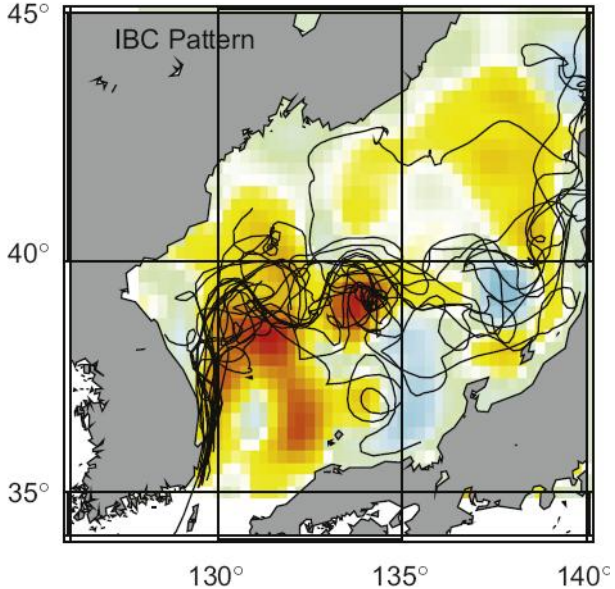


Minobe et al. (2004) Variance of temperature anomalies from climatological monthly means from 1957 to 1996.

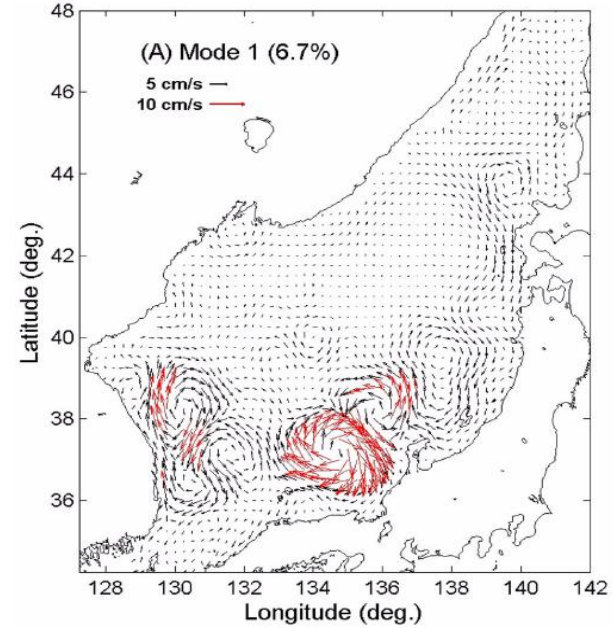


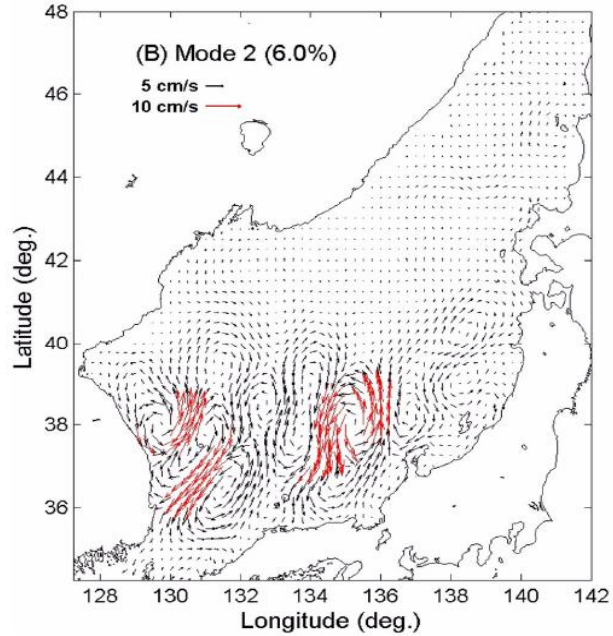


Color: SSH anomaly
Lines : trajectories of surface drifters



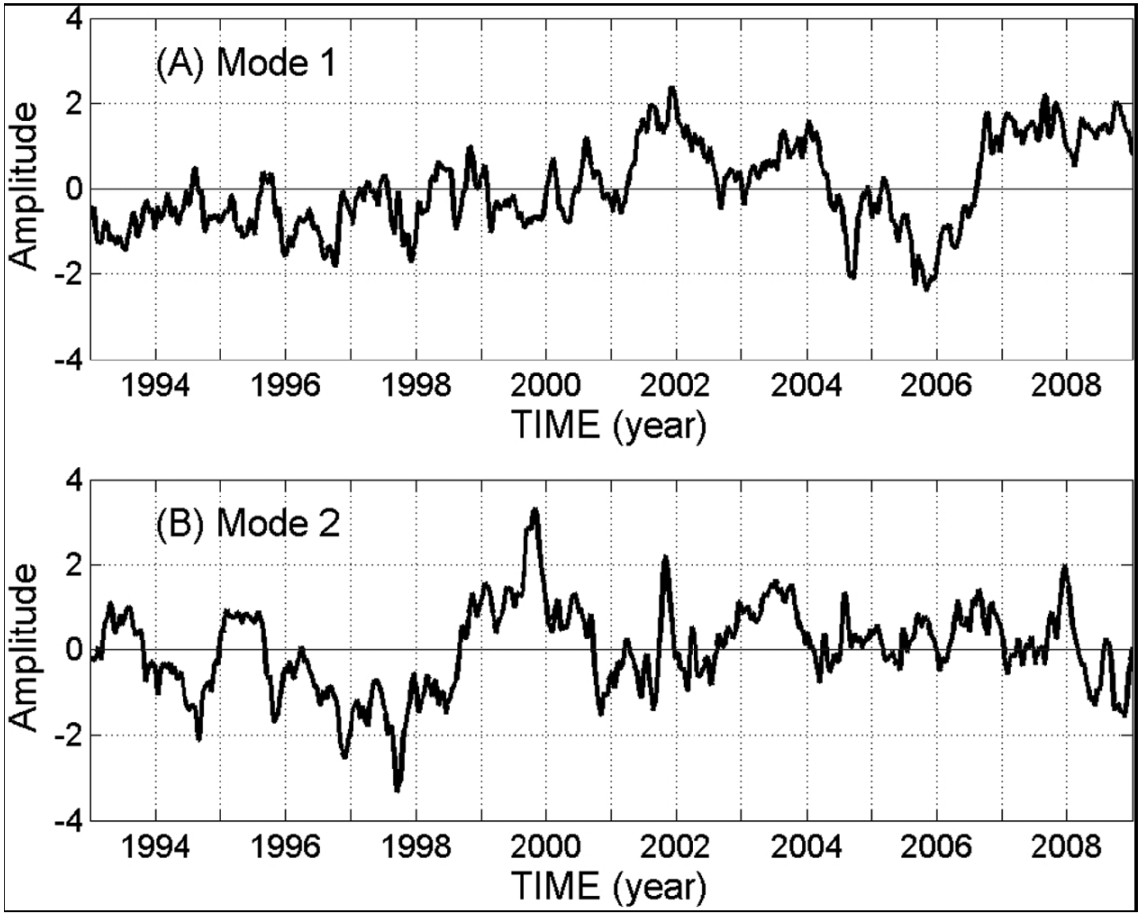
Lee and Niiler, 2010. Surface circulation from **drifters and sea surface height**.





Choi et al., 2012. Geostrophic currents from **sea surface height**.

1.1 Background



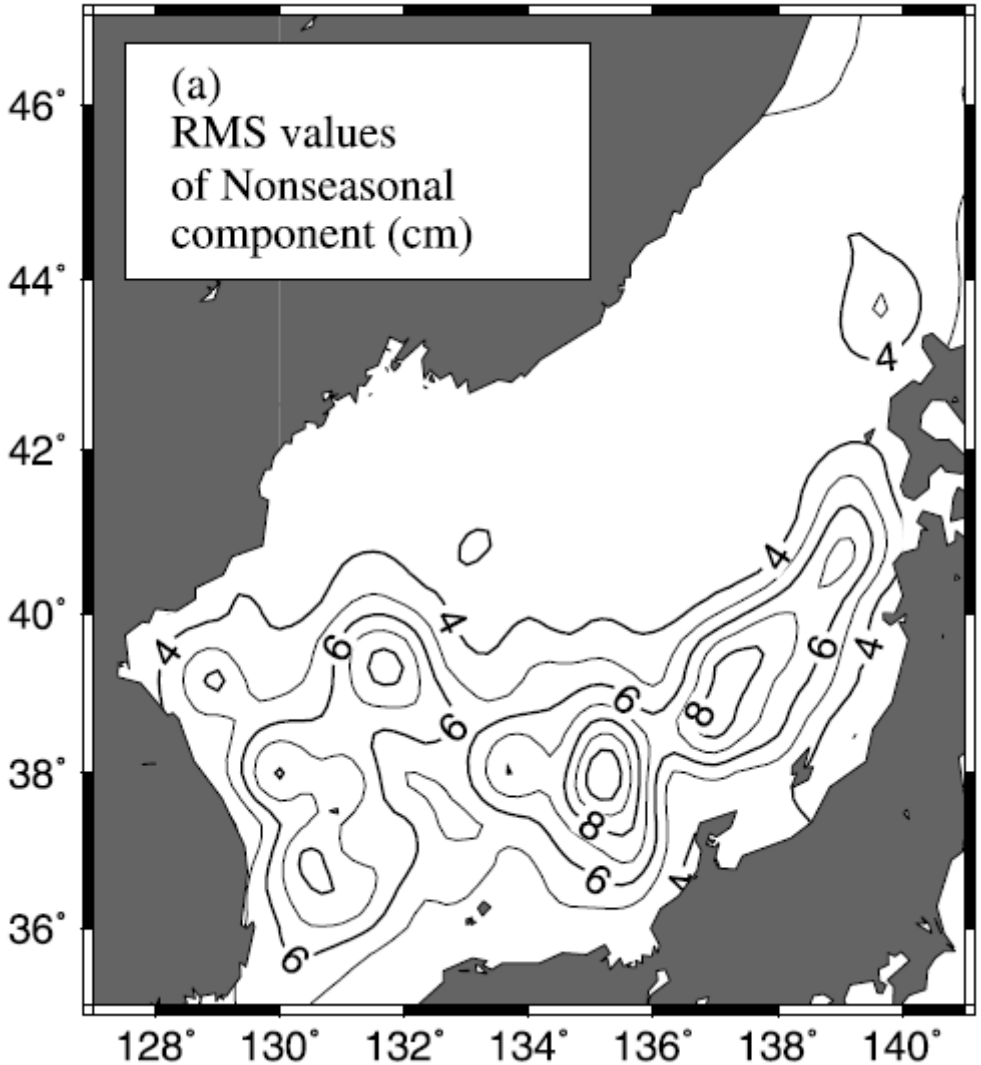
Intensification of EKWC

(relaxation of EKWC)

Meandering

Interannual variations

The amplitude time series of the first two EOF modes from 1993 to 2008.



The root-mean square (RMS) values of nonseasonal SSH (Choi et al., 2004)

What causes the interannual variability?

- Winds, SLP in the northwestern Pacific, Siberian High (Minobe et al. 2004; Choi et al. 2009)
- Open boundary condition (inflow and outflow variation) from the North Pacific
- Internal low-frequency variability, nonlinearity of the flow (Holloway et al., 1995; Hirose and Ostrovskii, 2000)

1.2 Objectives

- To reproduce inter-annual variation of surface circulation in the Japan/East Sea (JES)
- To find what induce the inter-annual variability of surface circulation in the JES

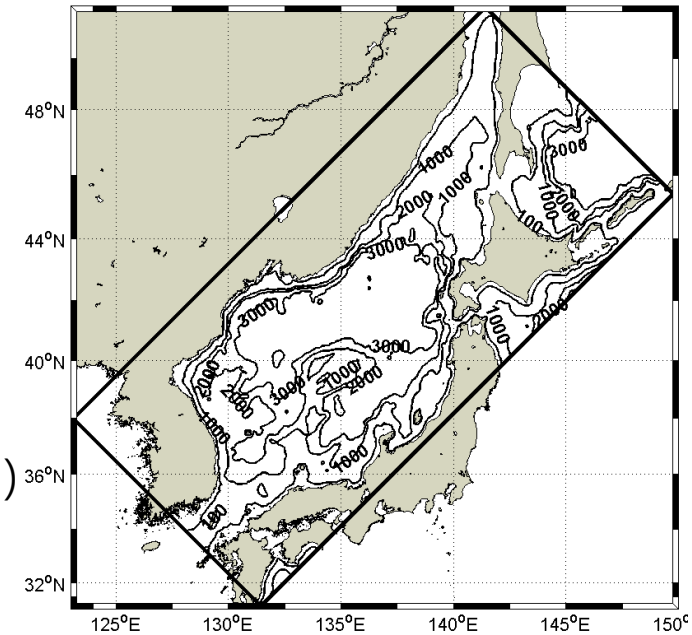
1. Inter-annual variation of **atmospheric condition** (wind, air temperature, pressure, solar radiation, humidity)
2. Inter-annual variation of **open boundary condition** (inflow and outflow transports, T, S)
3. **Internal** low-frequency **variability** within the JES

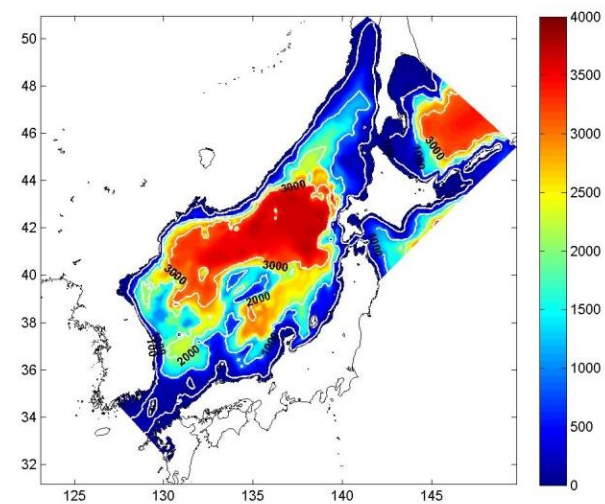
2. Data and Method

❖ROMS(Regional Ocean Modeling System)

1. Grid size:
   - Horizontal : 1/32° (3 km)
   - Vertical : 41 layers
2. Topography : ETOPO05
3. Initial Condition:
   Temperature and Salinity - WOA2001
   SSH and Current - Northwest Pacific Model (10 km)
4. Open boundary Data - Northwest Pacific Model (10 km)
5. Surface forcing: ECMWF daily data
6. River: Nakdong River
7. Tidal forcing: Oregon TPXO6 (M2, S2, O1, K1, N2, K2, P1, Q1, Mf, Mm 10 constituents)
8. Spin up: 7 years
9. Simulation: 2004 –2008 (5 years)

Bottom Topography





Experiment Design

	Atmospheric Forcing	**Open boundary data**	**Initial**	**Simulation**
EXP.1 (Control)				
EXP.2 (ATM)				
EXP.3 (OBC)				
EXP.4 (ITV)	Wind: 2005 daily Others: Monthly mean seasonal	Monthly Mean seasonal	2004.01	10 yr

Experiment Design

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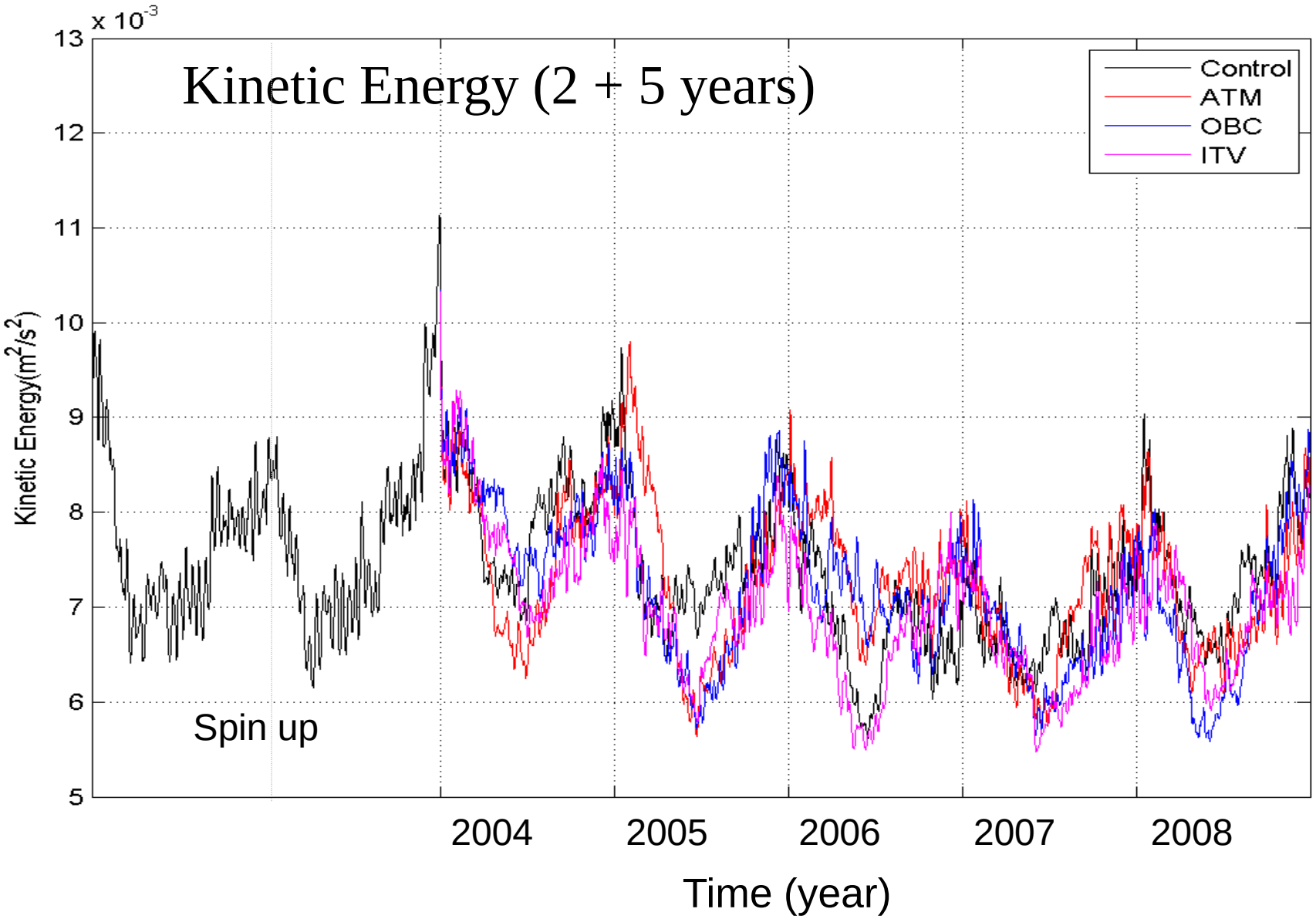
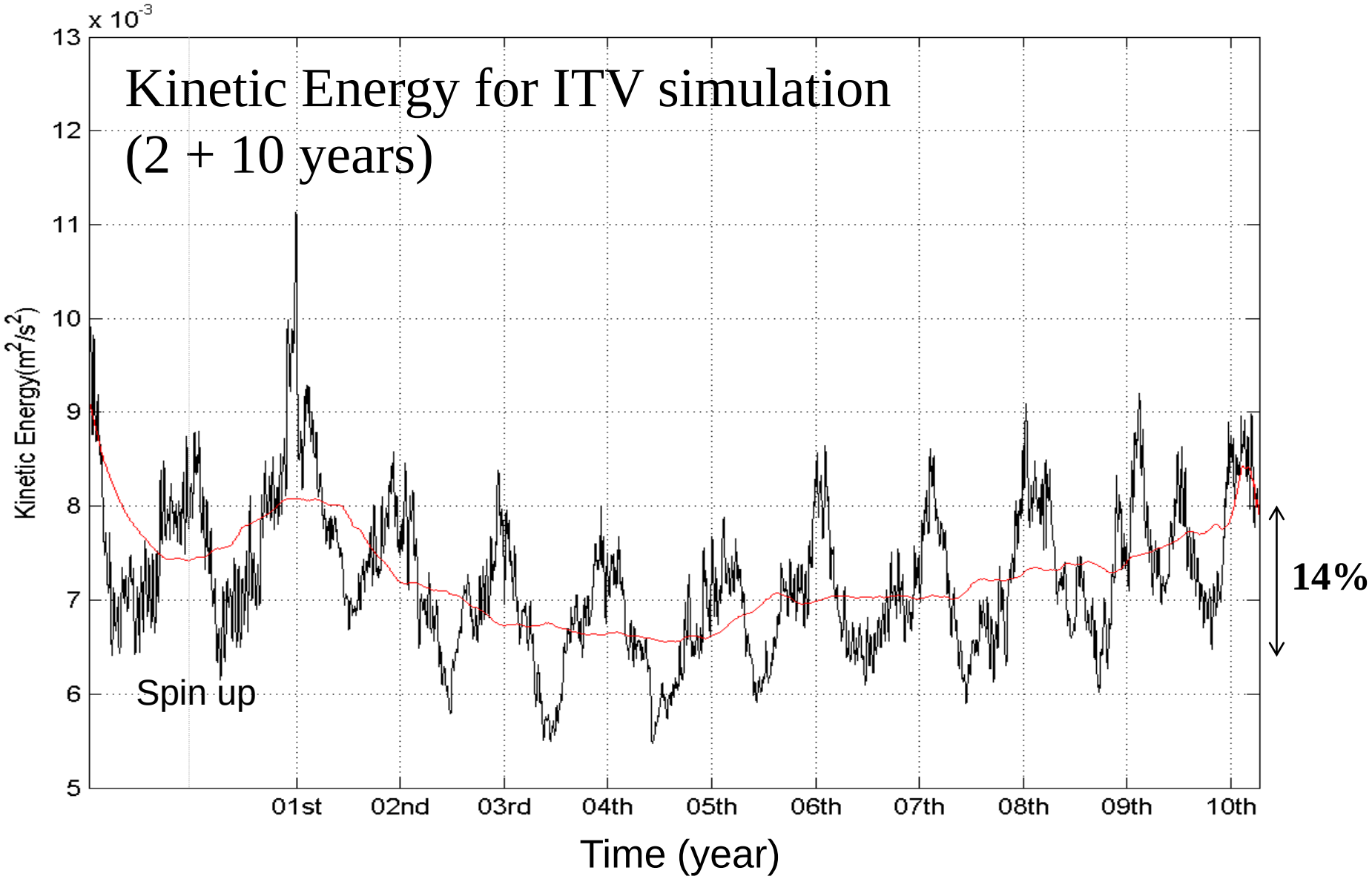
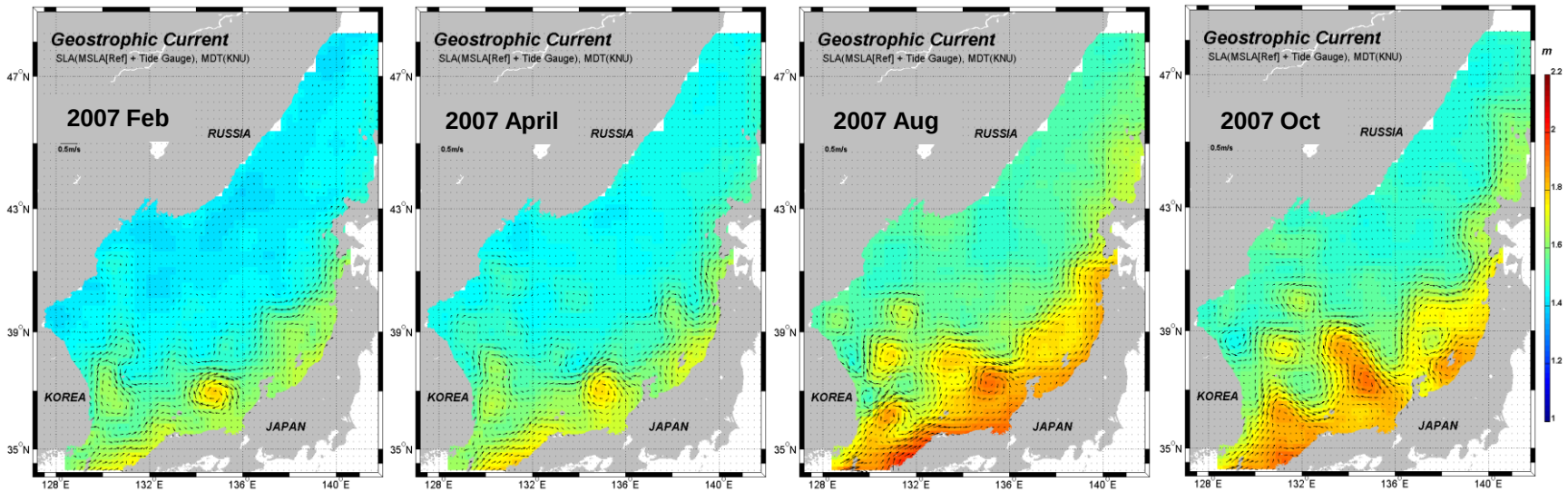

Kinetic Energy (2 + 5 years)
x 10^-3
13
12
11
10
9
8
7
6
5
Kinetic Energy(m^2/s^2)
Control
ATM
OBC
ITV
Spin up
2004
2005
2006
2007
2008
Time (year)


Kinetic Energy for ITV simulation
(2 + 10 years)
x 10^-3
13
12
11
10
9
8
7
6
5
Kinetic Energy(m^2/s^2)
Spin up
01st
02nd
03rd
04th
05th
06th
07th
08th
09th
10th
Time (year)
14%

3. Model Verification

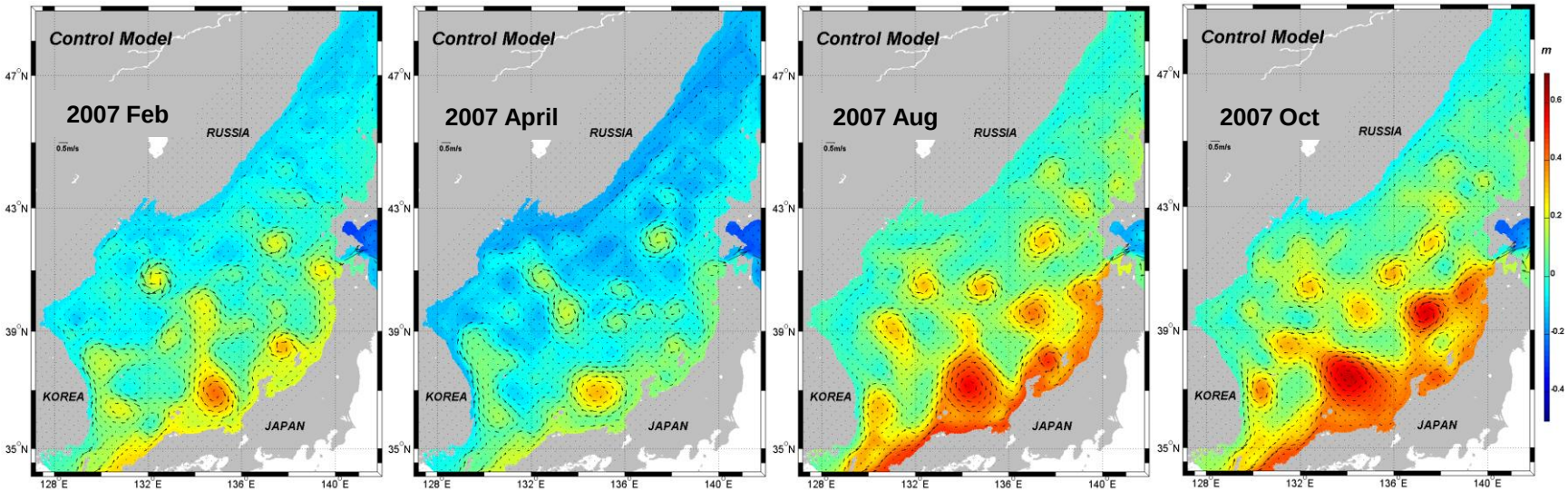
Sea Surface Height from satellite altimeter and surface geostrophic currents

Satellite SSH



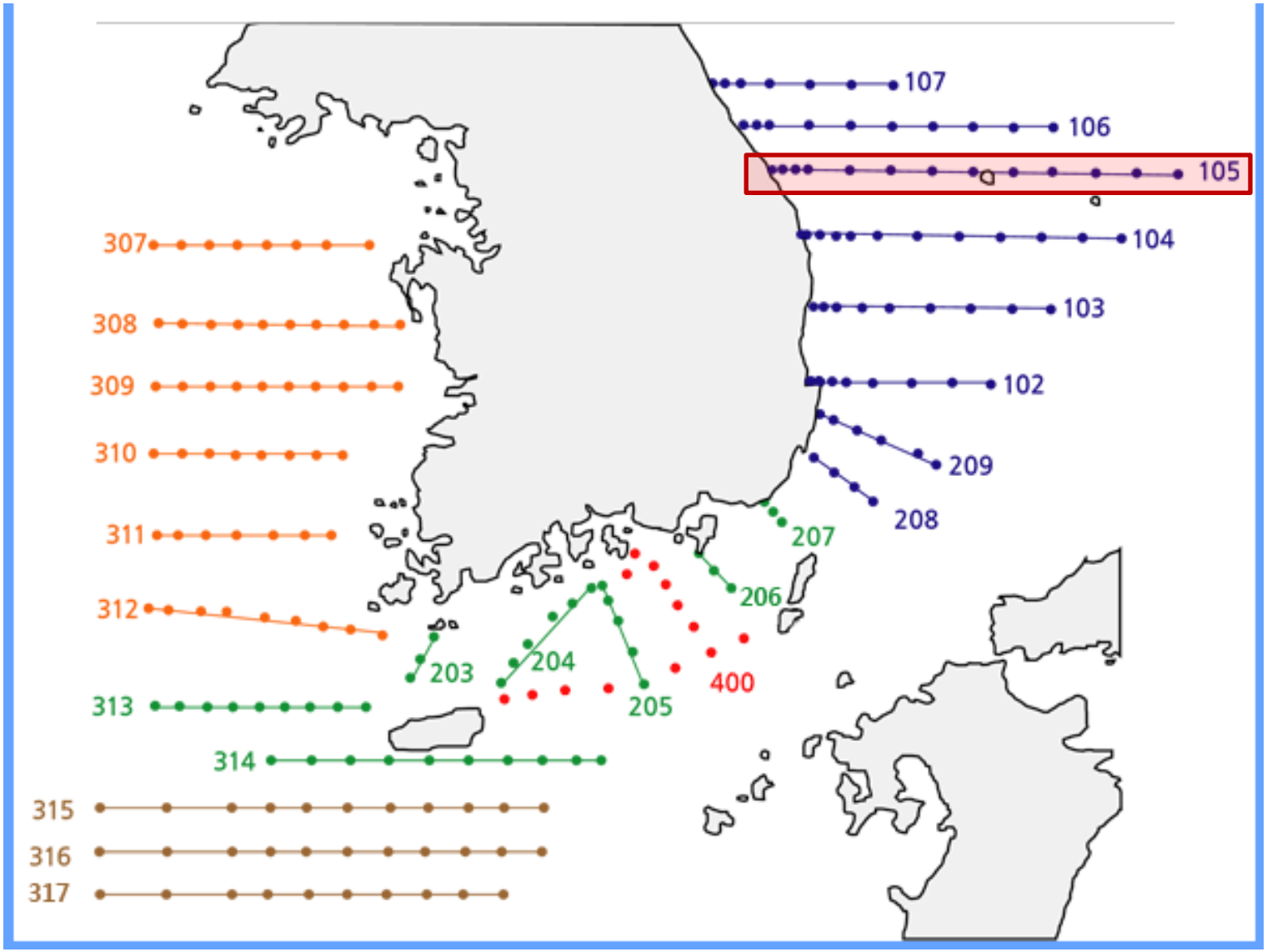
2007 Feb 2007 April 2007 Aug 2007 Oct

Control Model



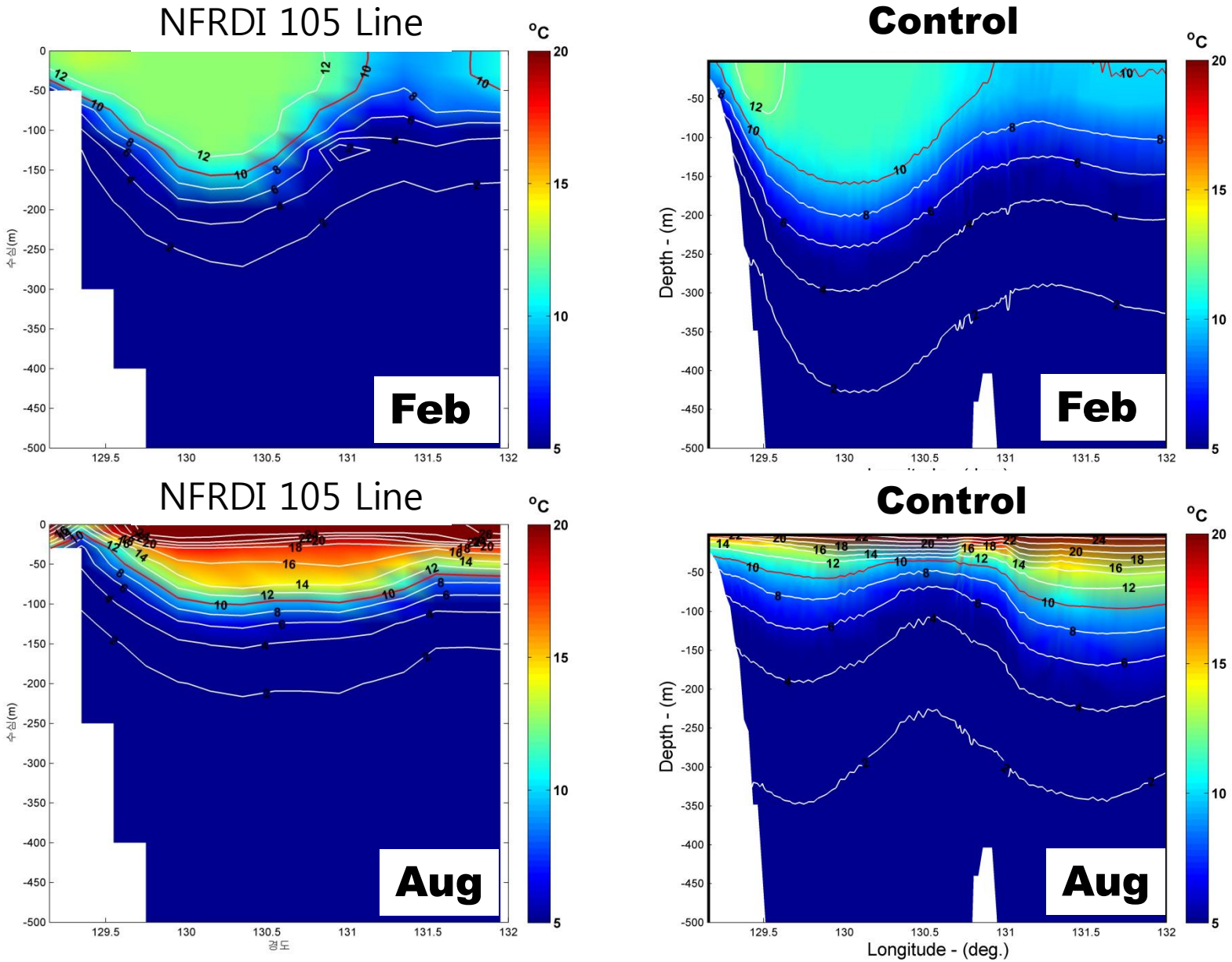
3. Model Verification

Temperature Observation along NFRDI line 105



2007

Temperature CI = 2°C



3. Model Verification

Horizontal temperature distribution (NFRDI)

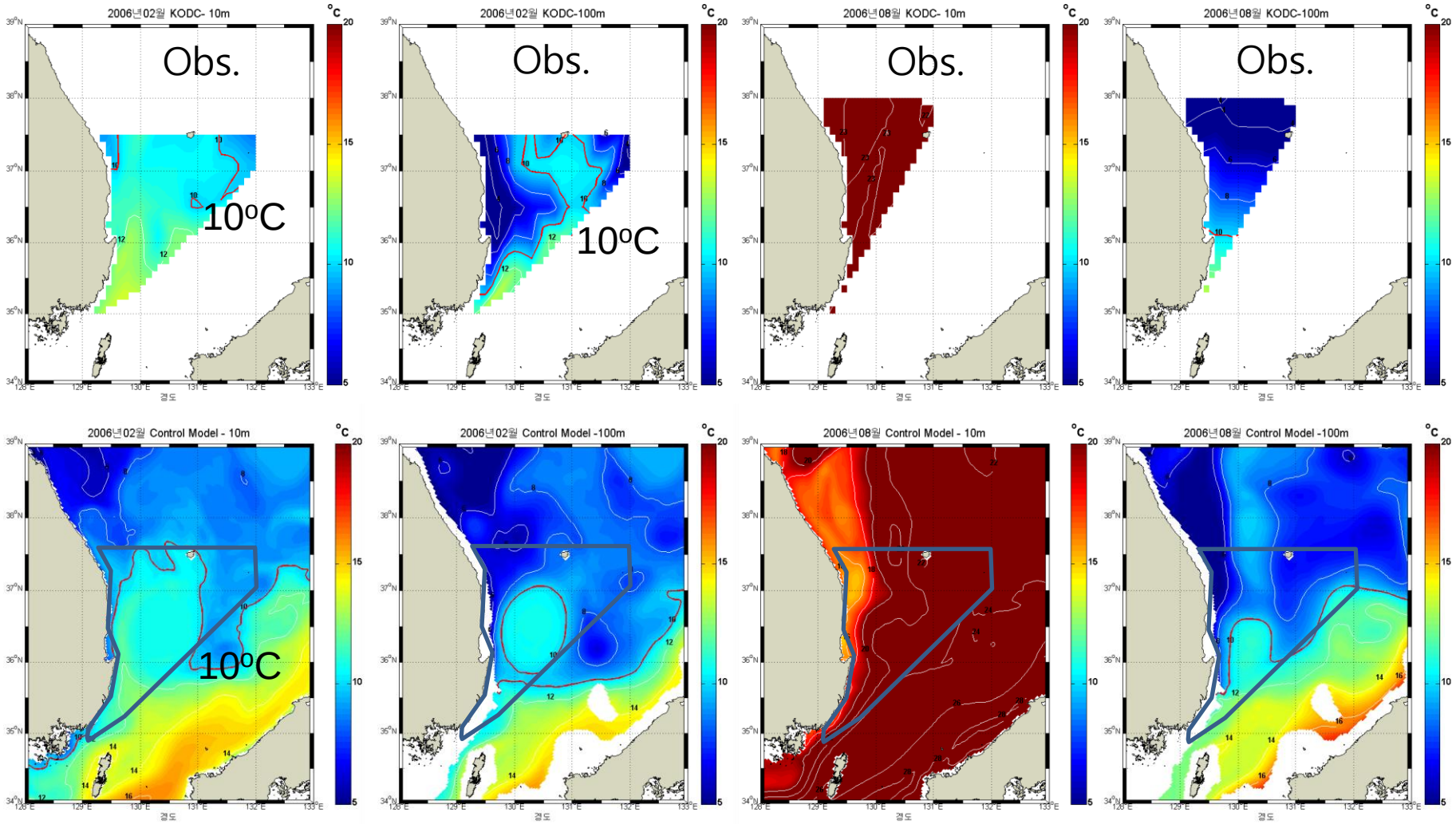
at 10 m and 100 m

Temperature February 2006

Temperature August 2006

CI = 2°C

10 m | 100 m | 10 m | 100 m

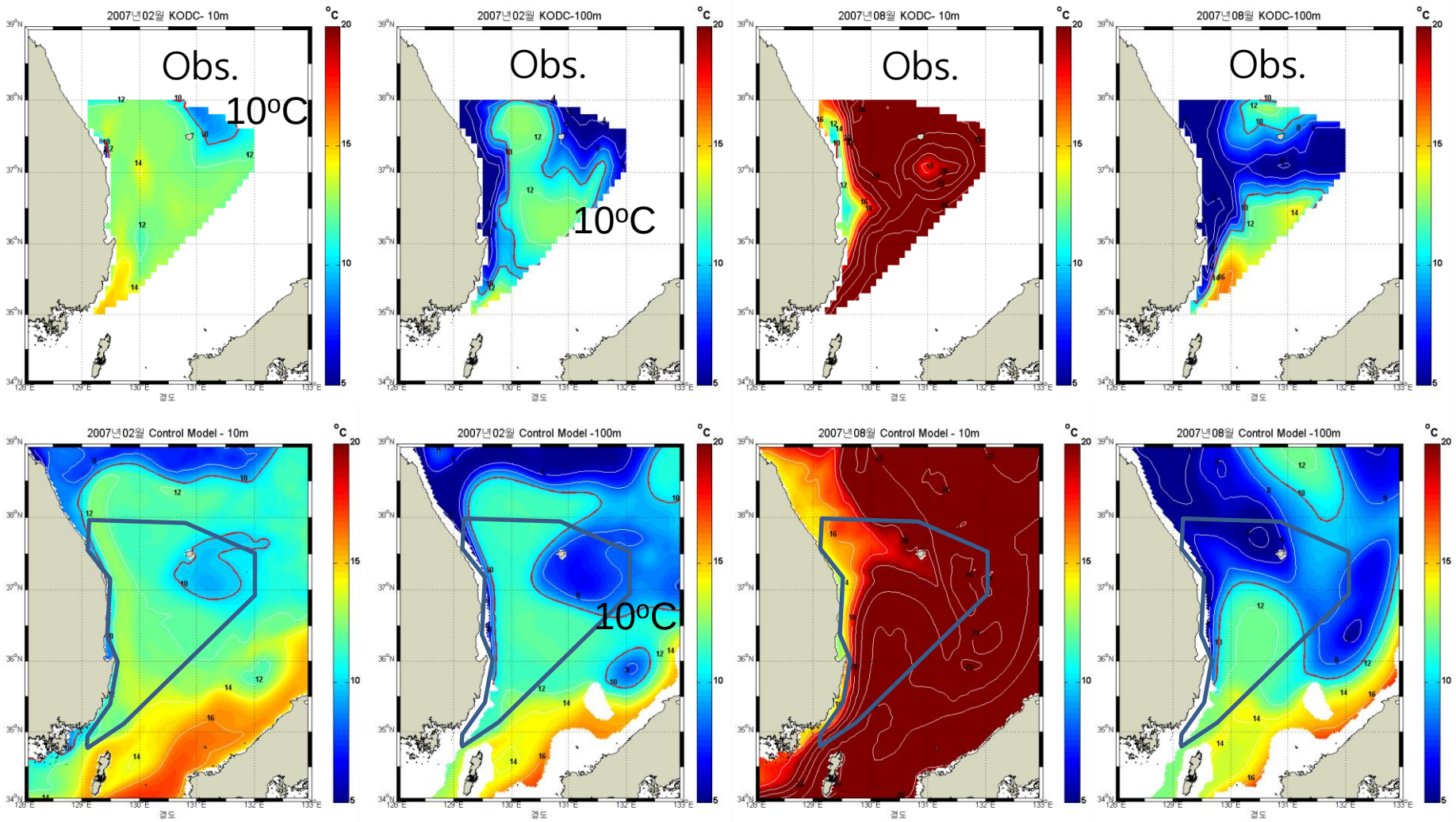


Temperature February 2007

Temperature August 2007

CI = 2°C

10 m | 100 m | 10 m | 100 m



Model | Model | Model | Model

- Control model produces the surface currents comparable to the surface gestrophic currents from the satellite altimetry data

- Horizontal and vertical distribution of temperature is similar to the observation in the southwestern part of the JES

- *Temperature is higher than the observation below the seasonal thermocline in the model*

- *Excess number of eddies in the northern part of the JES*

4. Result

Effects of ITV, atmospheric forcing, and open boundary data on

4.1 Sea Surface Temperature

4.2 Sea Surface Height

(1) Mean SSH

(2) RMS of SSH anomaly

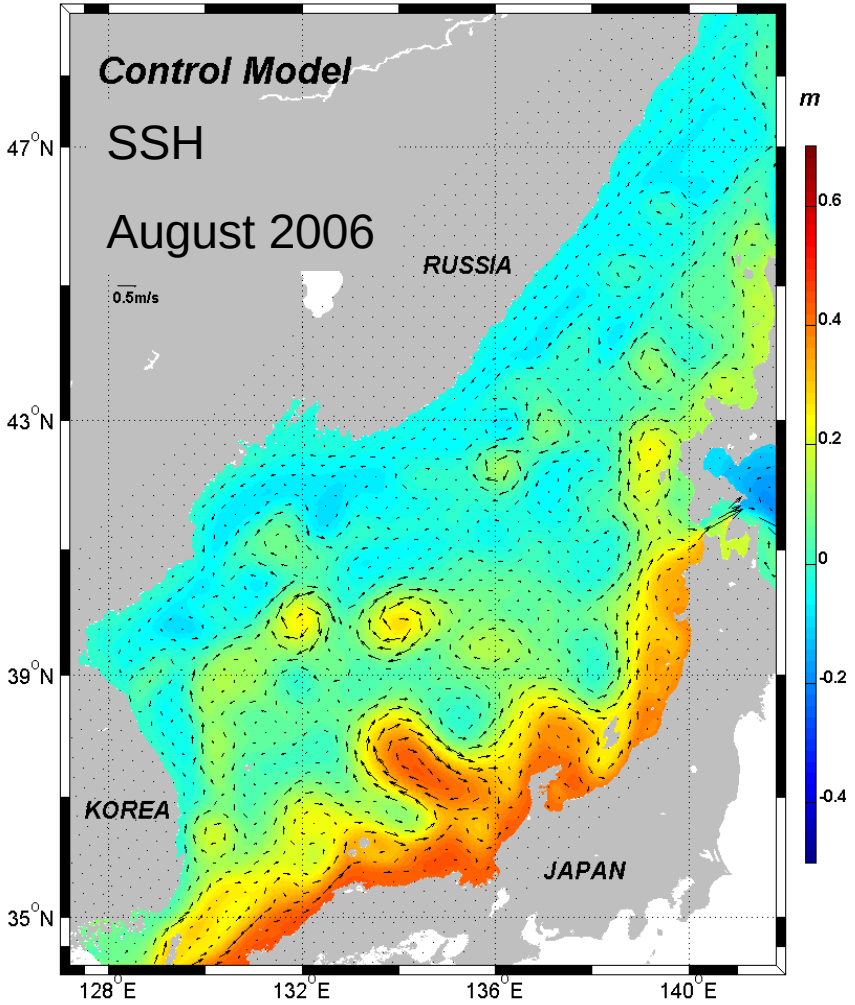
4.3 Variation of temperature at 100 m

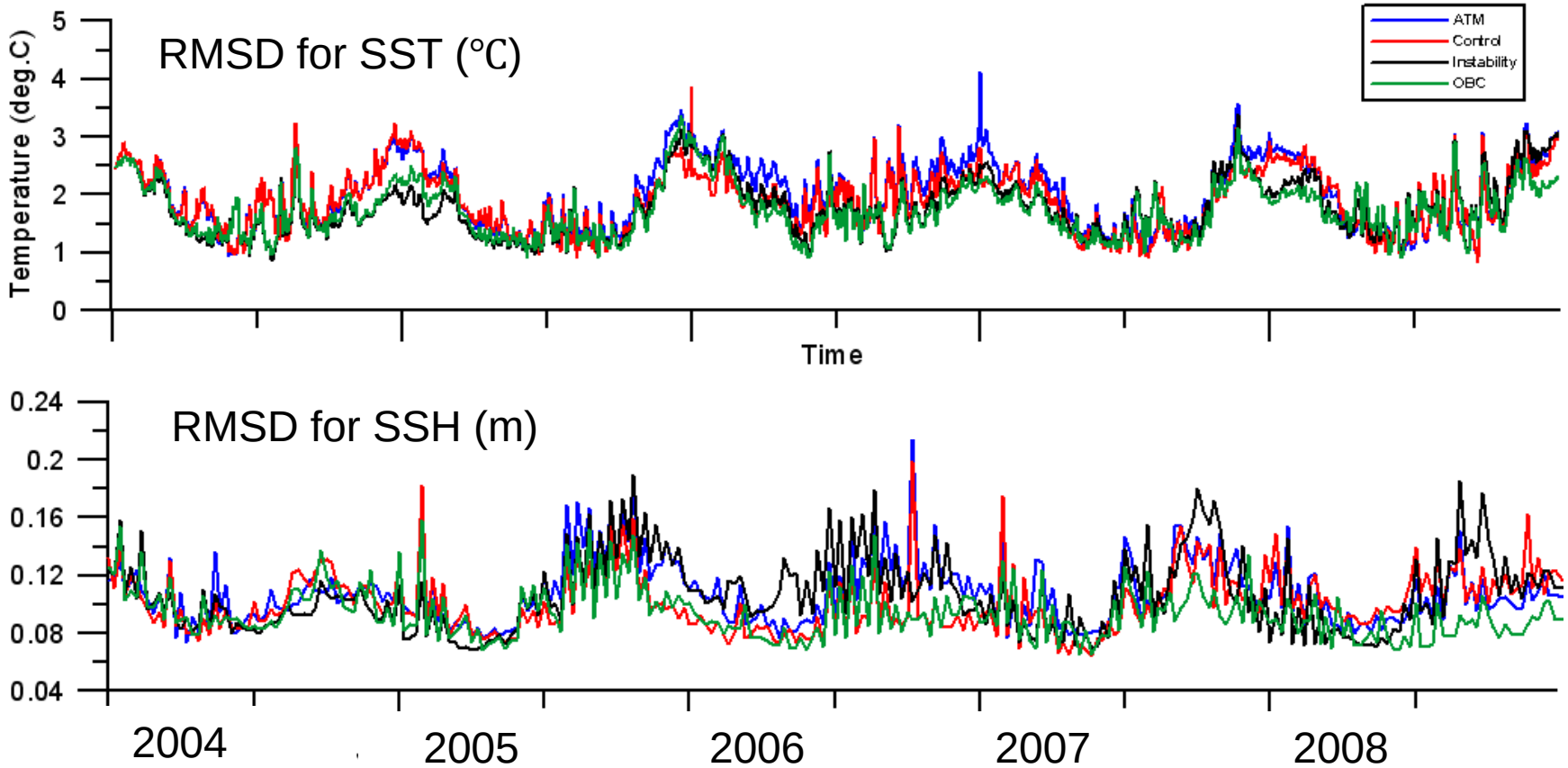
4. Result

4.1 Root Mean Square Difference for SST and SSH

- rmsd= $$\sqrt{\frac{\sum_{i=1}^{n}(M_i - O_i)^2}{n}}$$

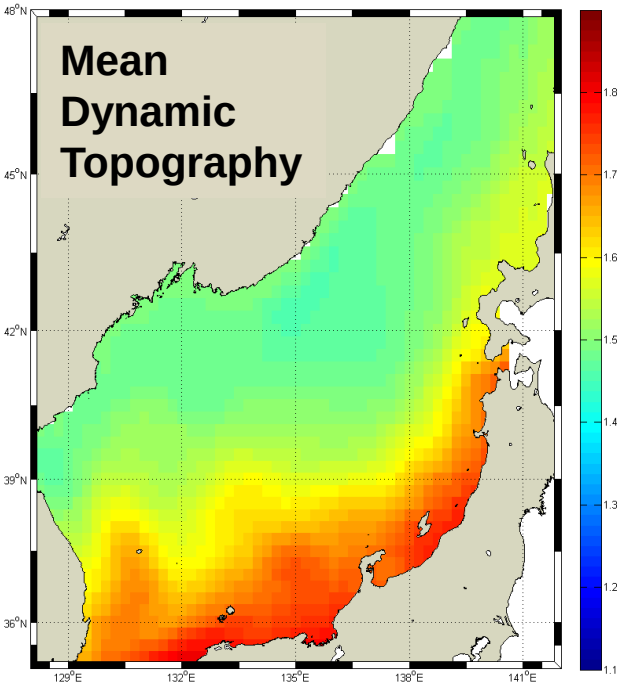
- M_i= Modeled value at i grid cell
- O_i= Observed value at i grid cell



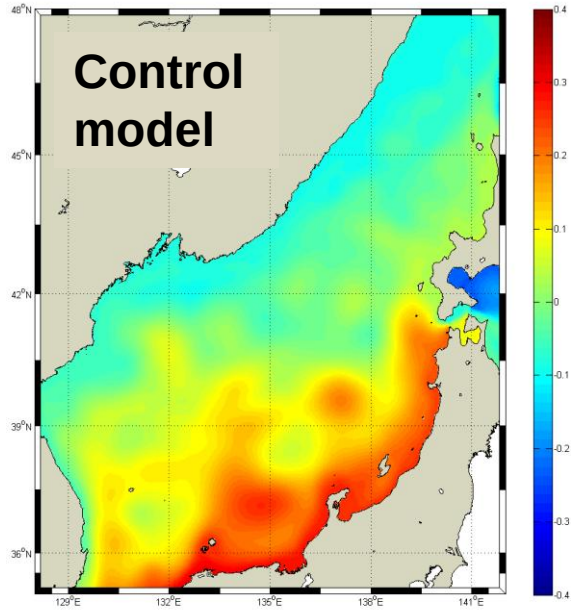


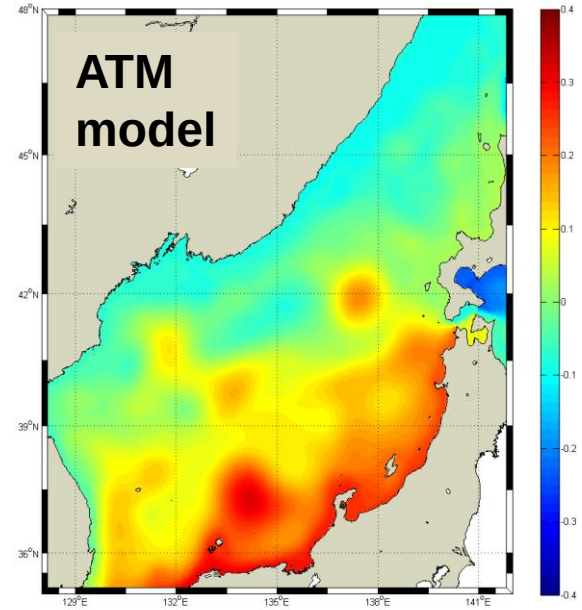
Simulations	SST (℃)	SSH (m)
Control	1.91	0.1014
ATM	2.02	0.1082
OBC	**1.75**	**0.0942**
ITV	1.80	0.1075

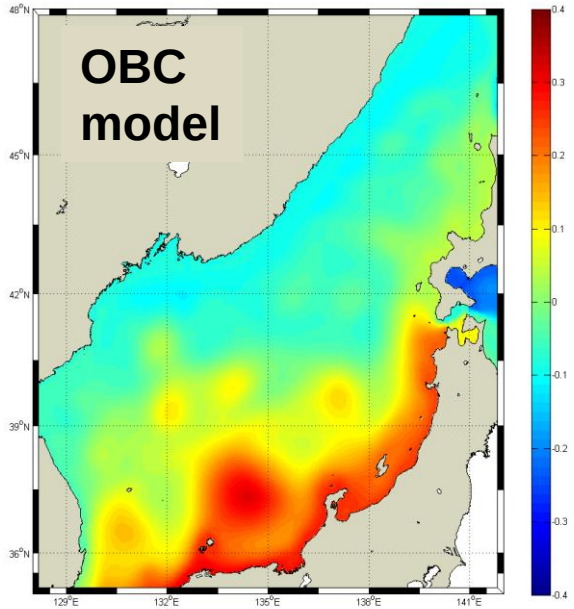
4.2.1. Mean SSH (2004-2008)

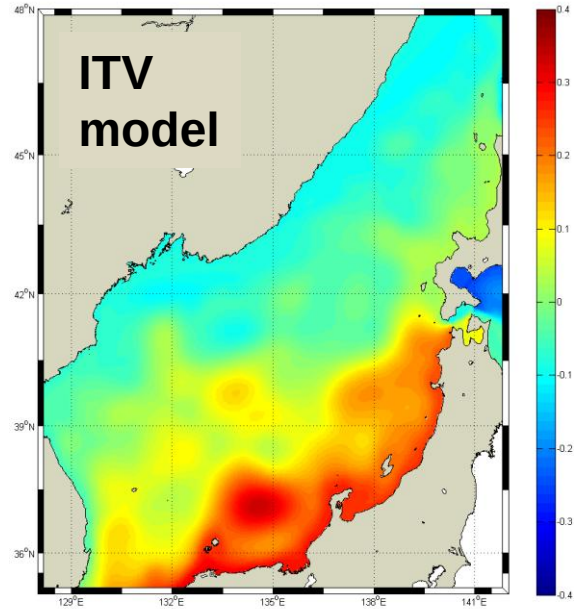


Hydrographic and Satellite altimeter data



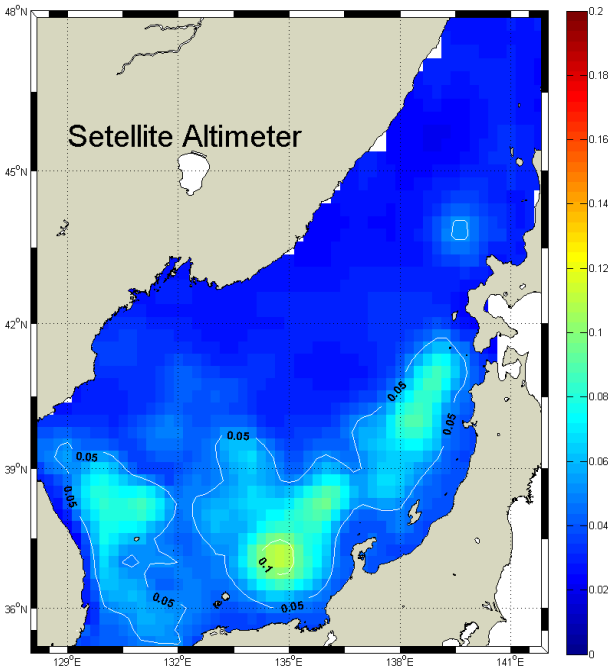




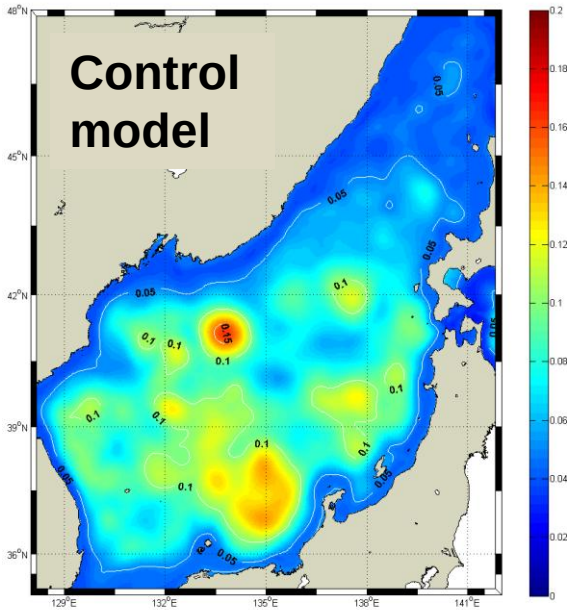


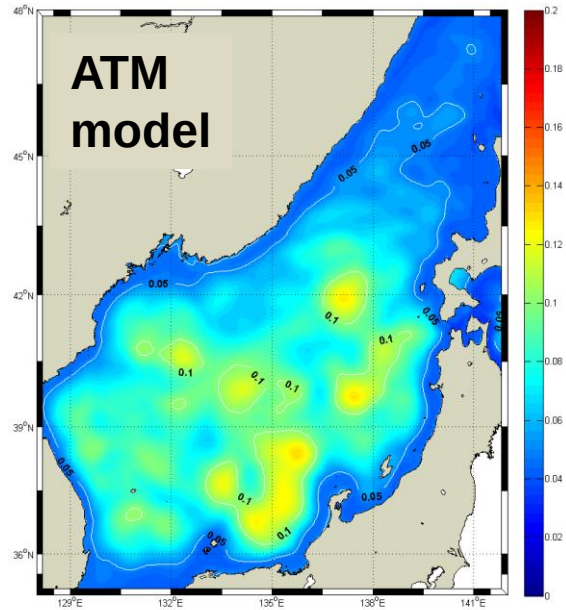
4.2.2. RMS of SSH anomaly (Variability)

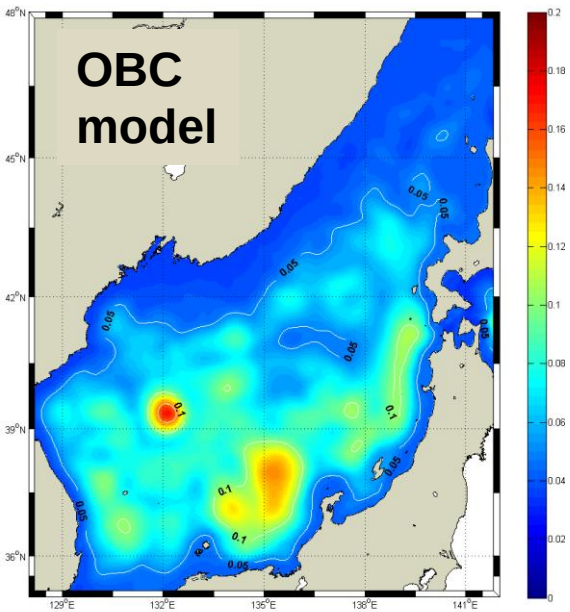
Nonseasonal SSH Variability (RMS)

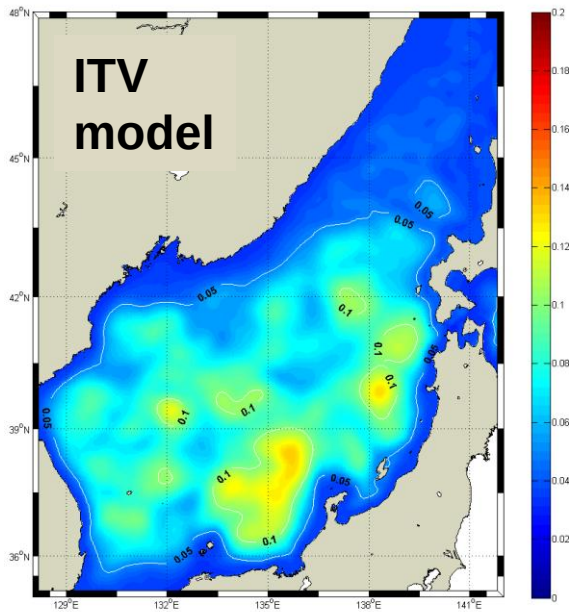


Satellite altimeter data









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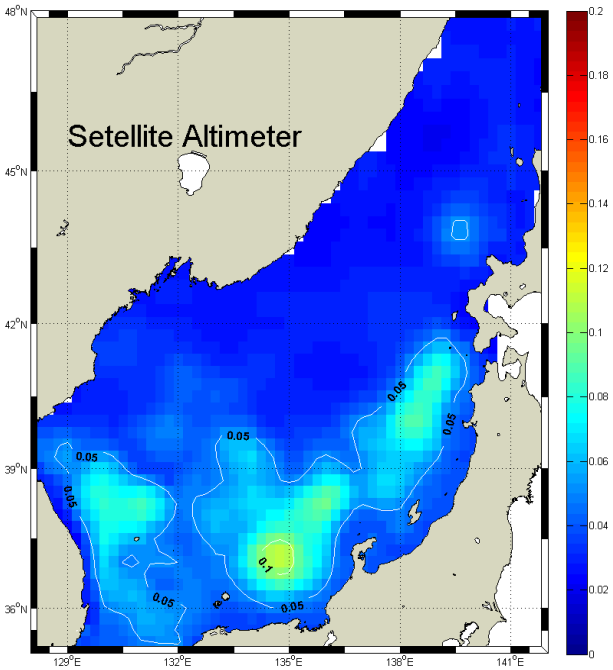
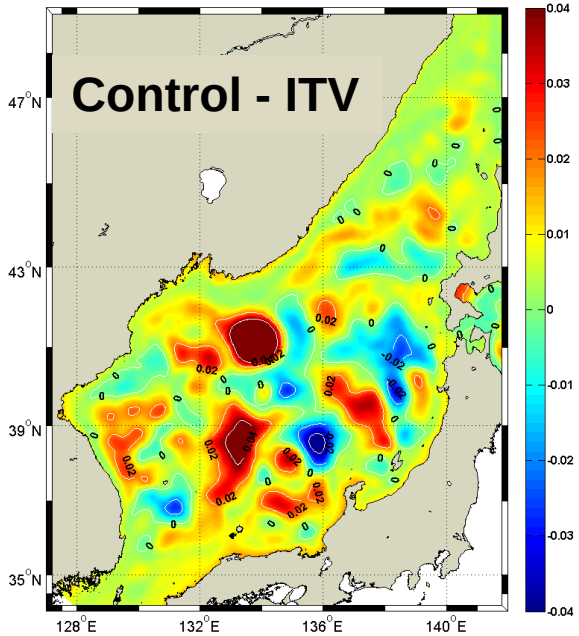
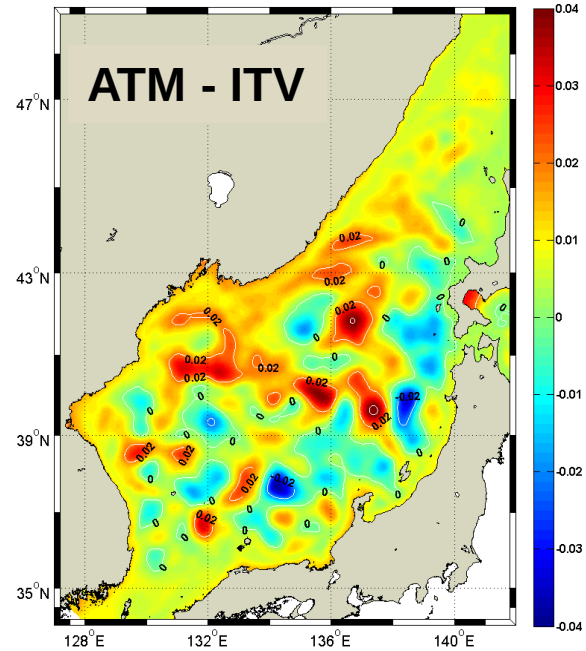
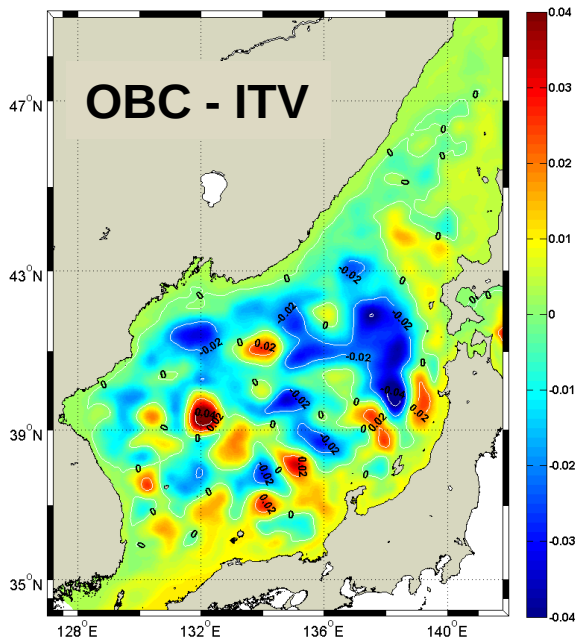
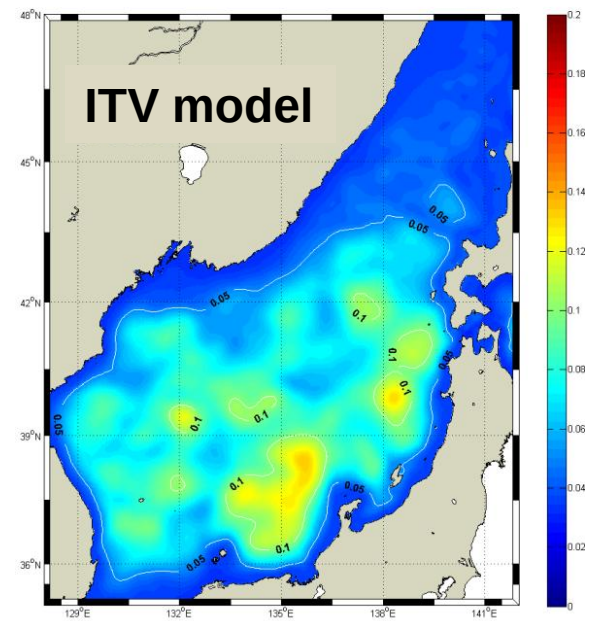


Satellite altimeter data

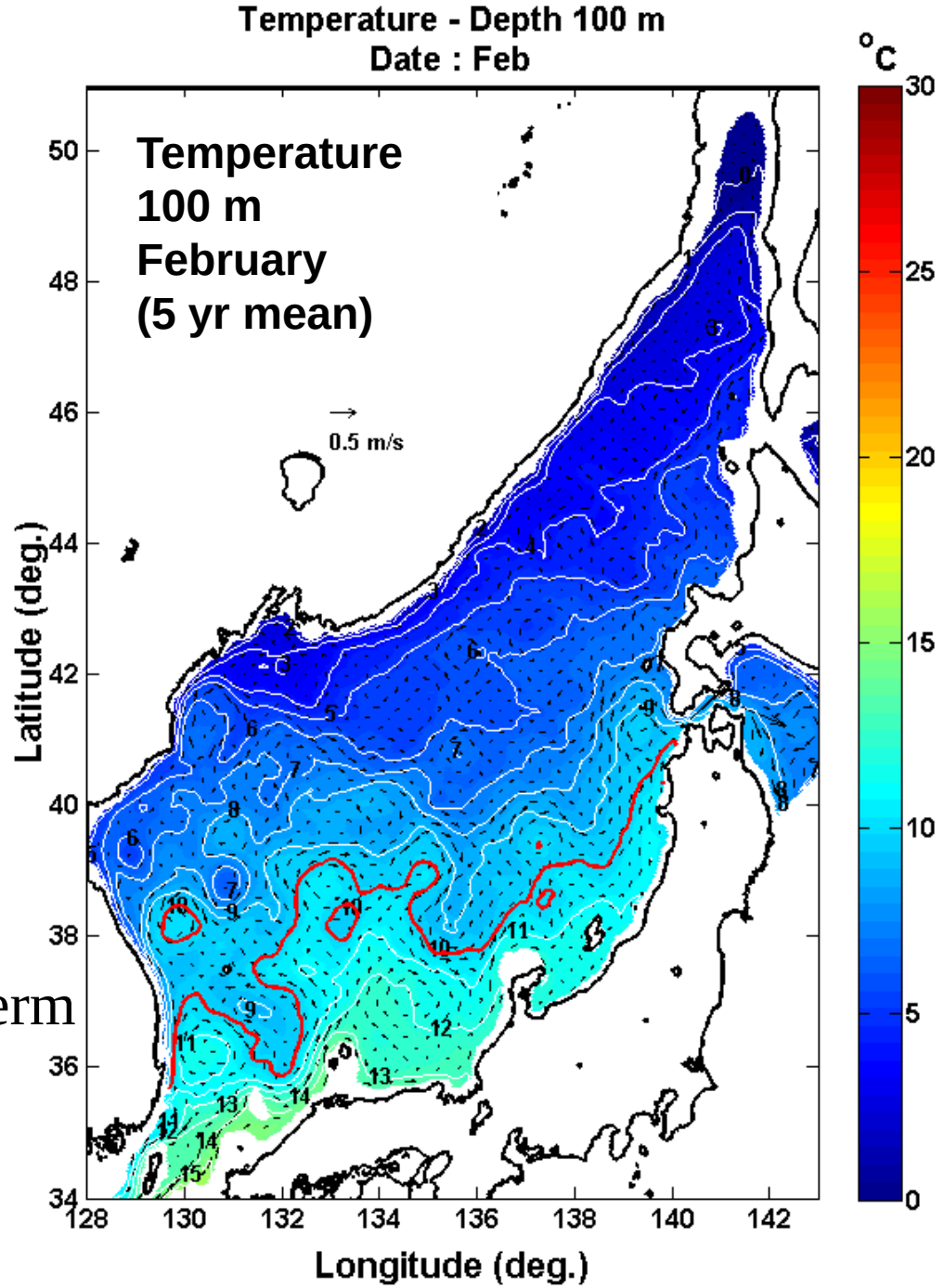








4.3 Variation of Temperature at 100 m

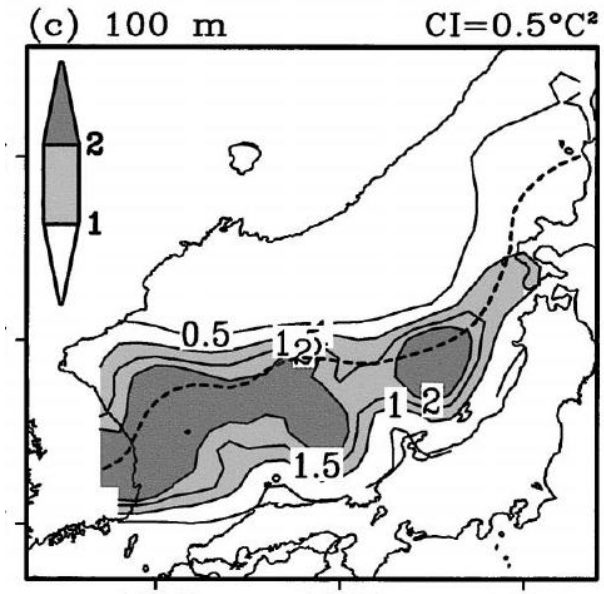


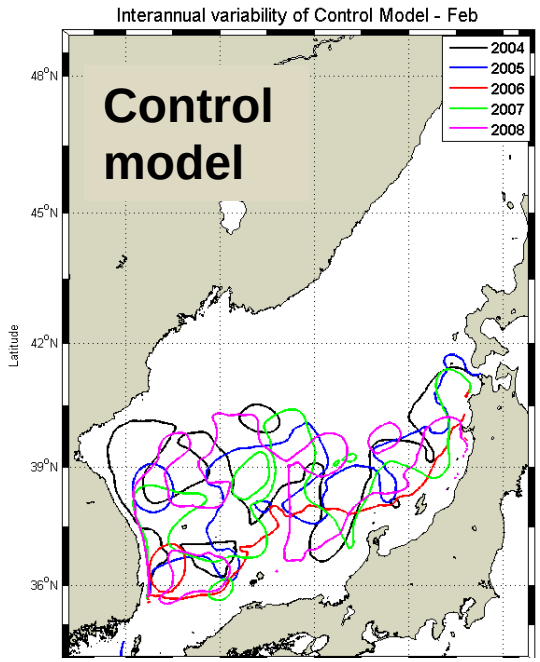
Contour interval = 1°C

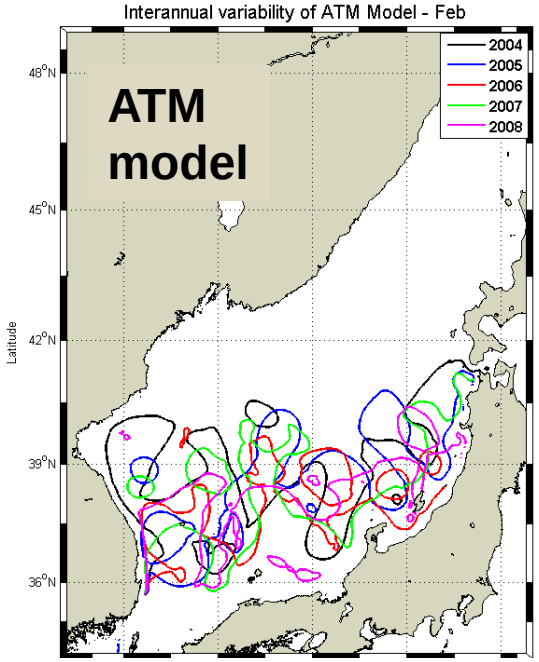
Red line indicates 10°C isotherm

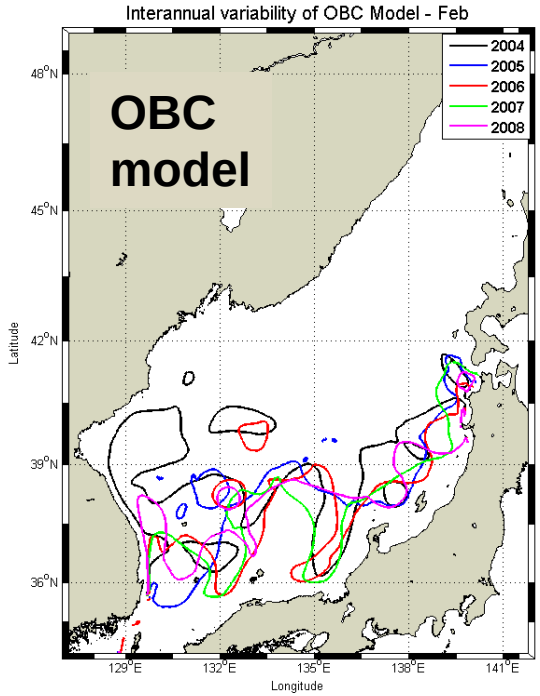
10°C isotherm at 100 m in February

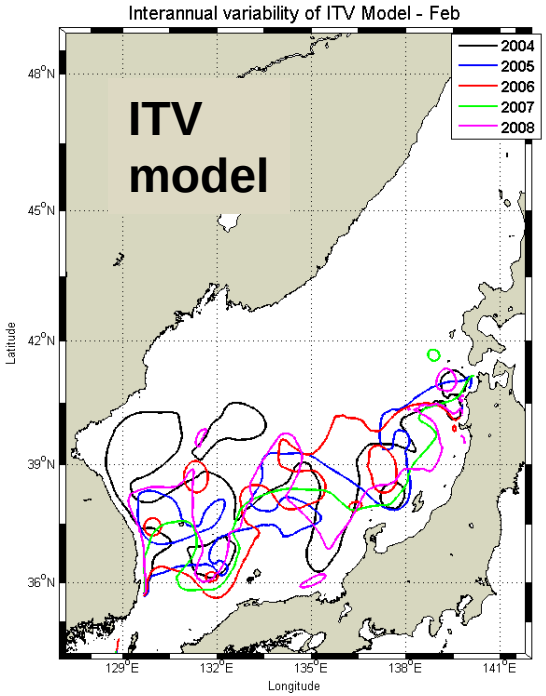
Temperature Variance
Minobe et al. (2004)





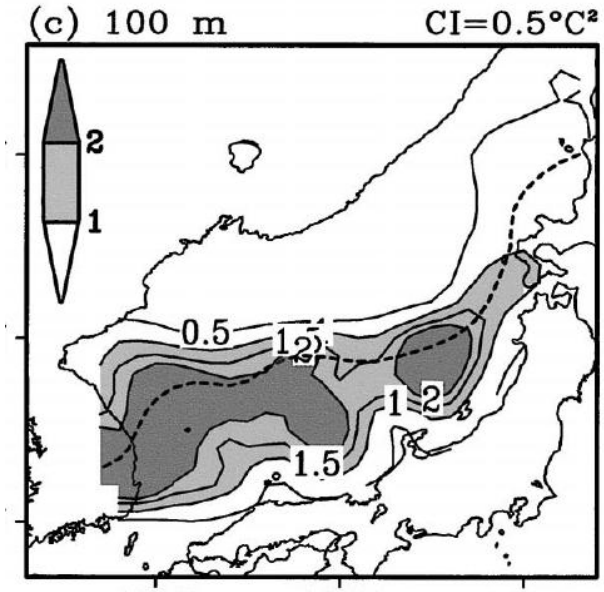


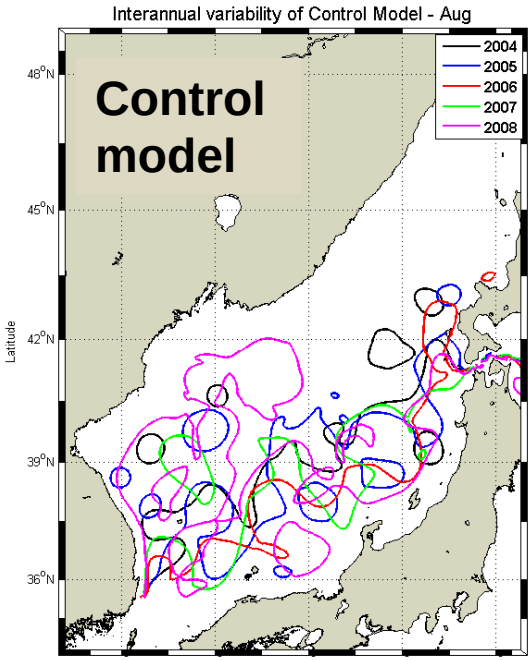


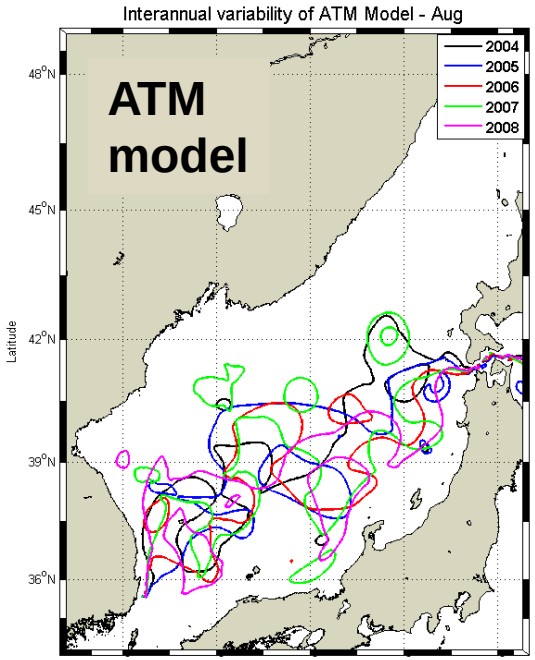


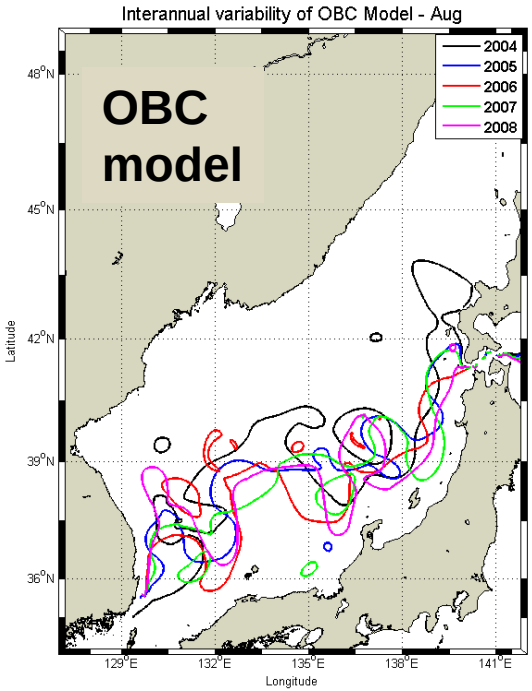
10°C isotherm at 100 m in August

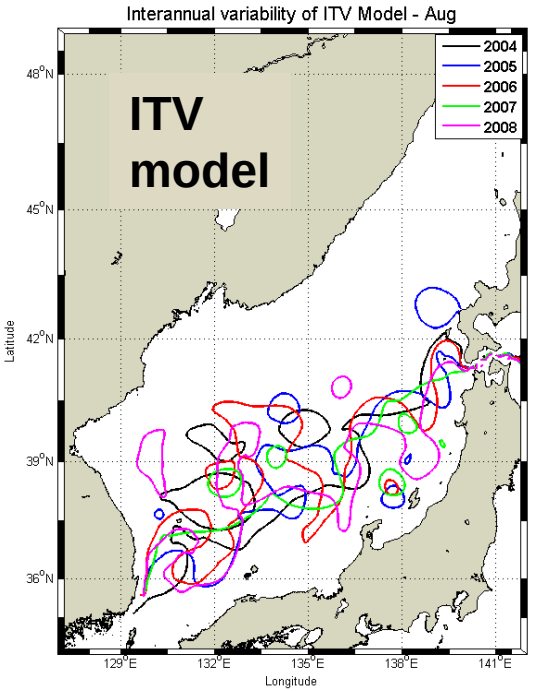
Temperature Variance
Minobe et al. (2004)











- RMSDs of SST and SSH between models and the observation are about 1.9^{o}C and 10 cm

- When the interannual variations of open boundary data are included (OBC model), RMSDs of SST and SSH decrease relative to those from mean seasonal forcing (ITV model)

- *When the interannual variations of atmospheric forcing are included (*ATM *and* Control *models), RMSDs of SST and SSH did not decrease*

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- *When the interannual variations of atmospheric forcing are included (*ATM *and* Control *models), RMSDs of SST and SSH did not decrease*

- Interannual variations in the **Yamato and Ulleung Basin** are related to the <u>internal low-frequency variability</u> of the flow.

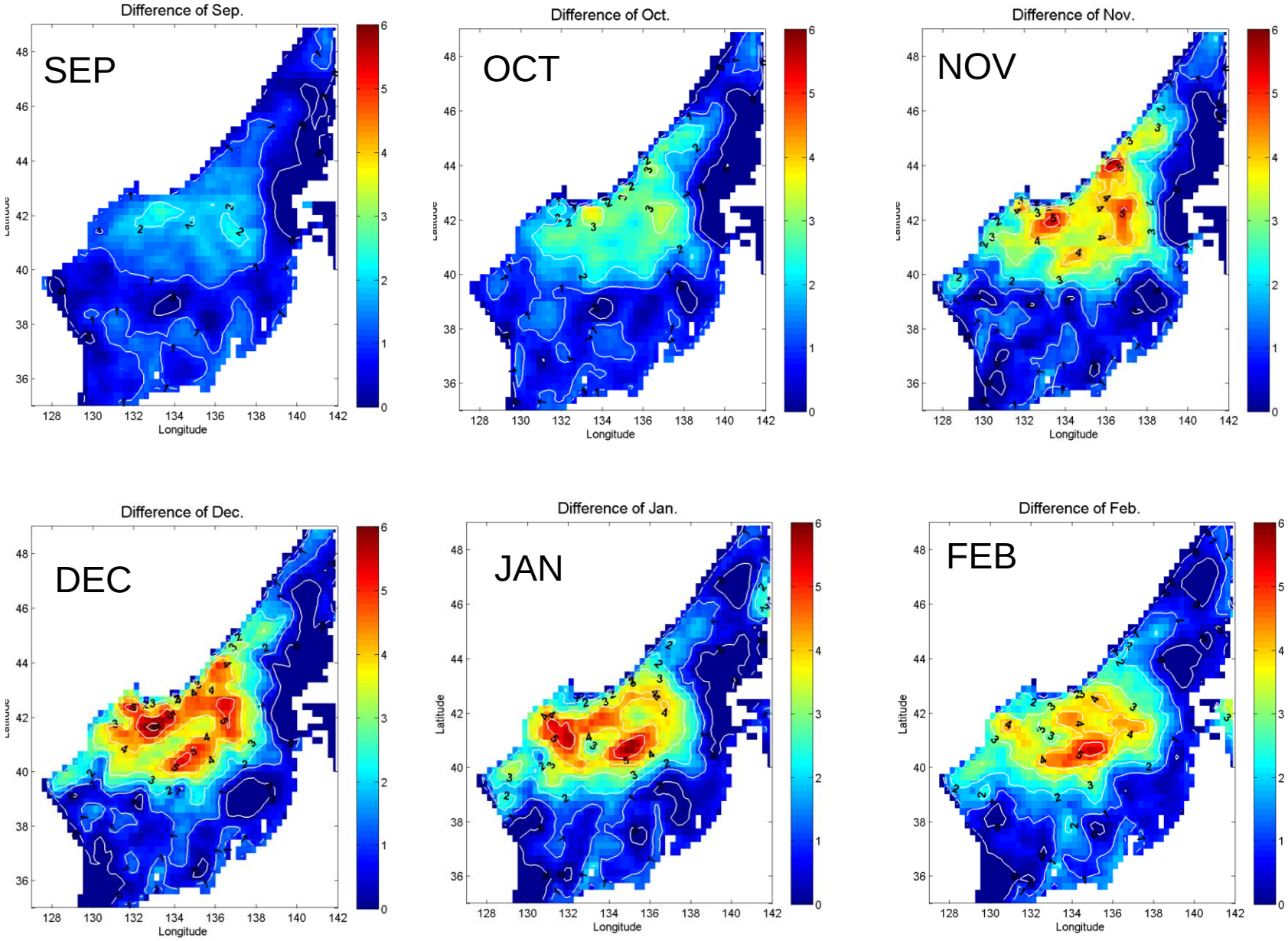
- *Enhanced Interannual variations in the* ***Ulleung Basin*** *might be related to the <u>interannul variations of OBC and ATM forcing</u>*

5. Discussion

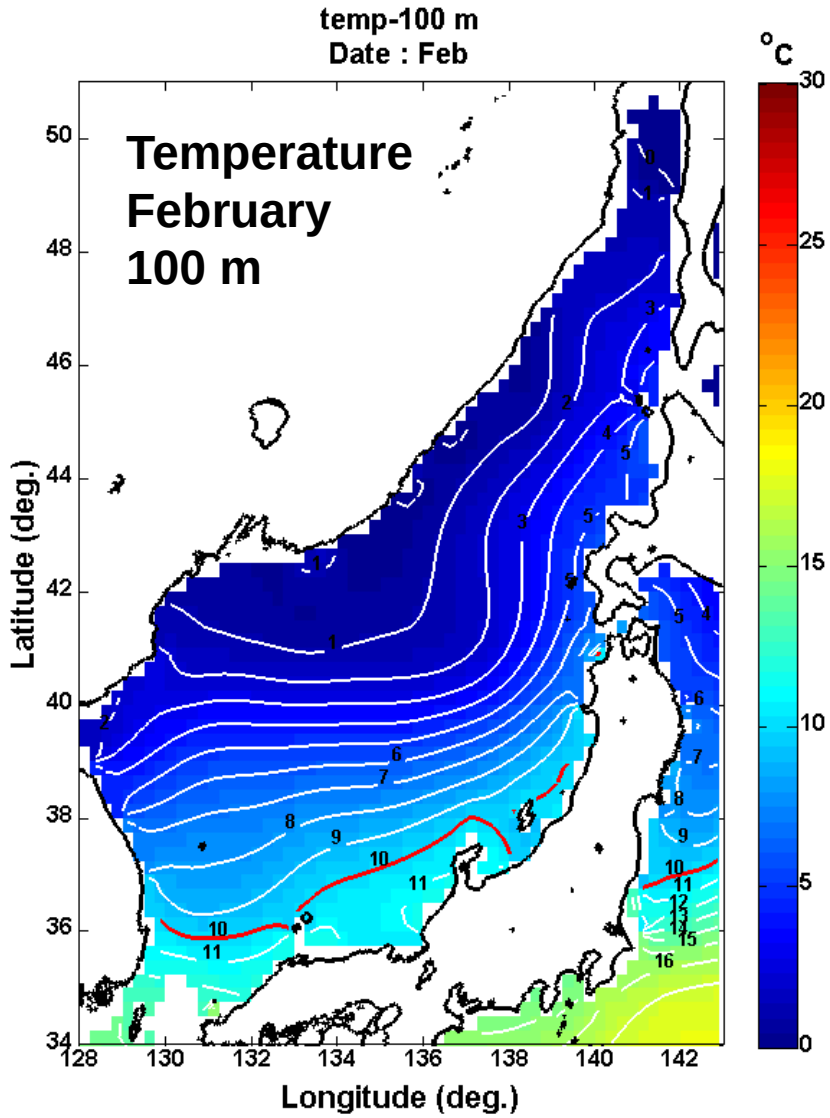
Why do we have large (1.9^{o}C) SST RMSD between satellite observation and models?

Why there are many eddies in the northern part of the JES?

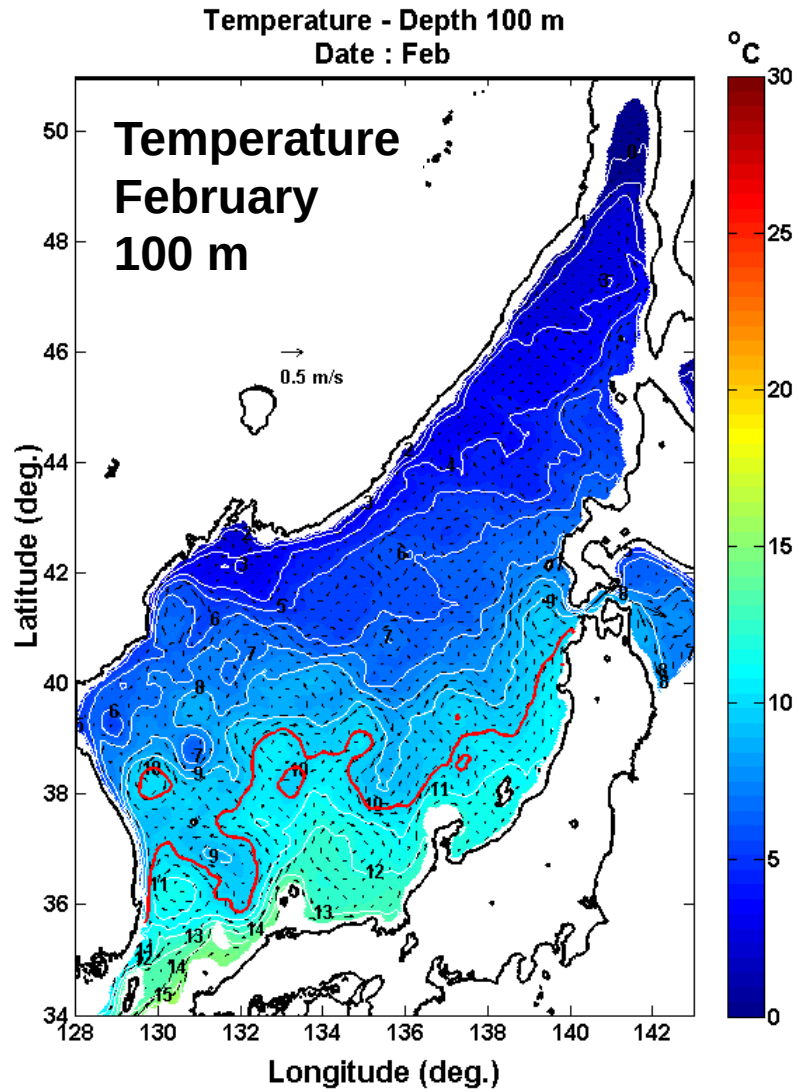
Difference in SST (Model – Satellite)



WOD09

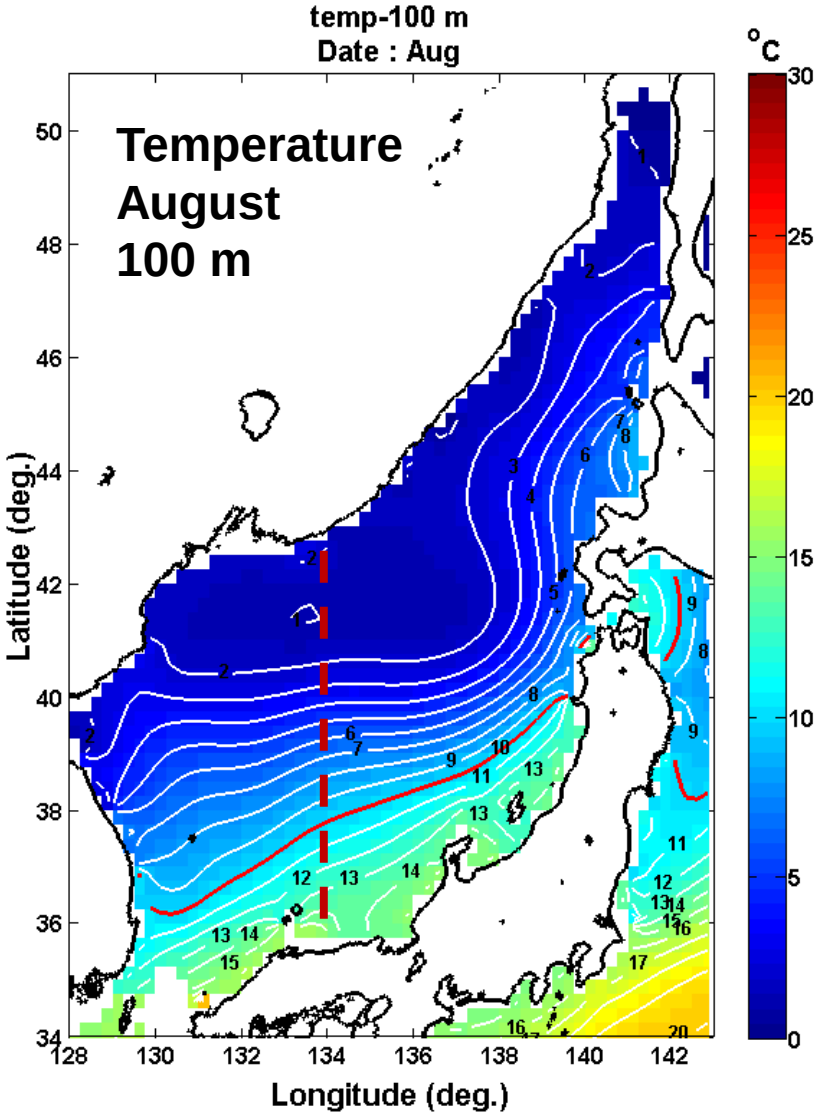


Control Model (5 year mean)

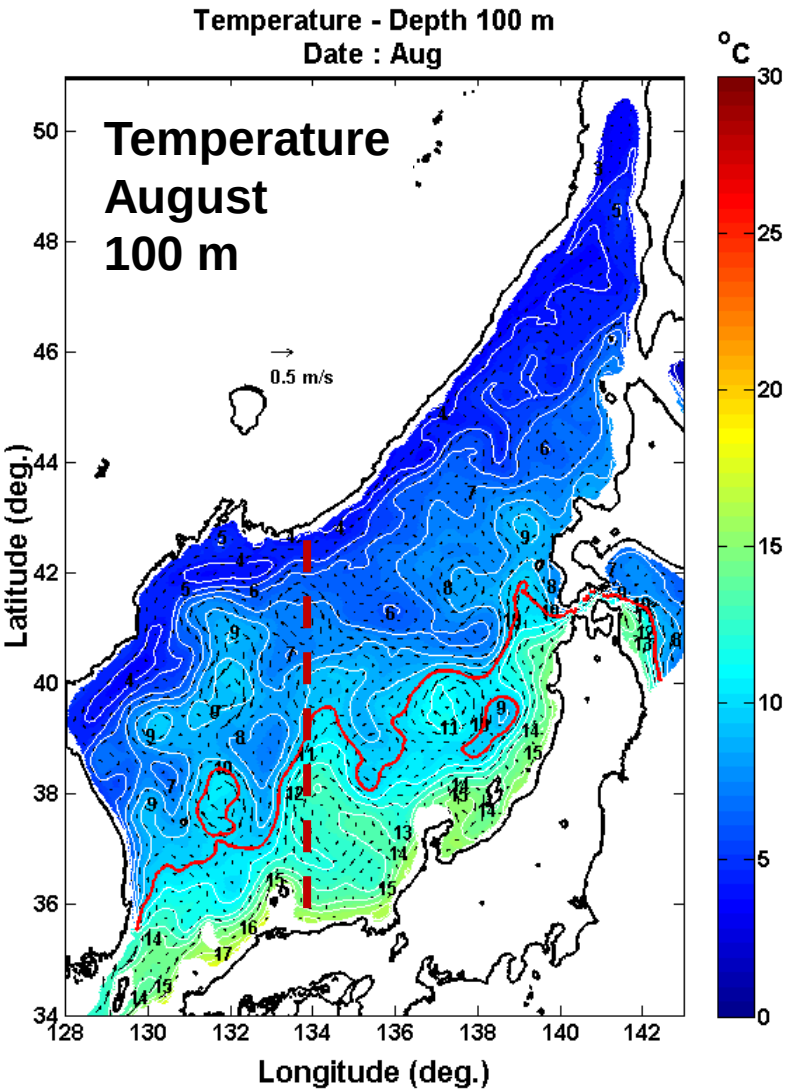


Temperature CI = 1°C

WOD09



Control Model (5 year mean)



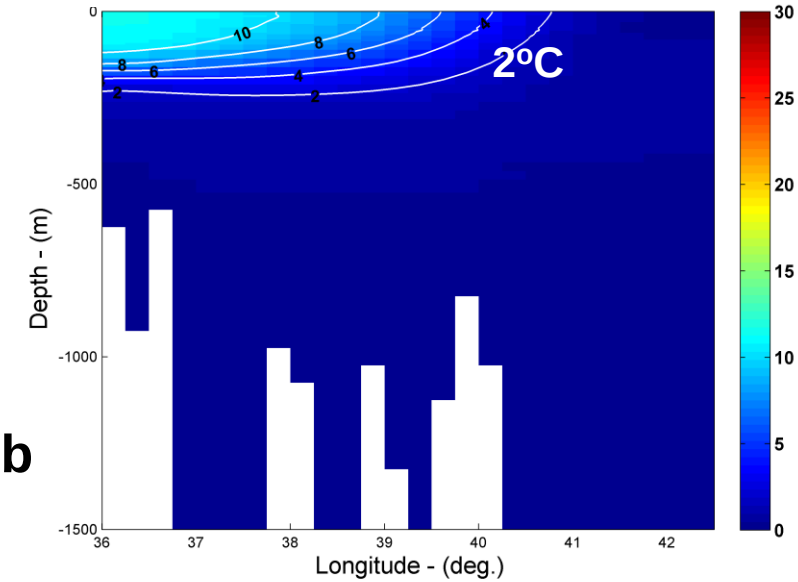
Temperature CI = 1°C

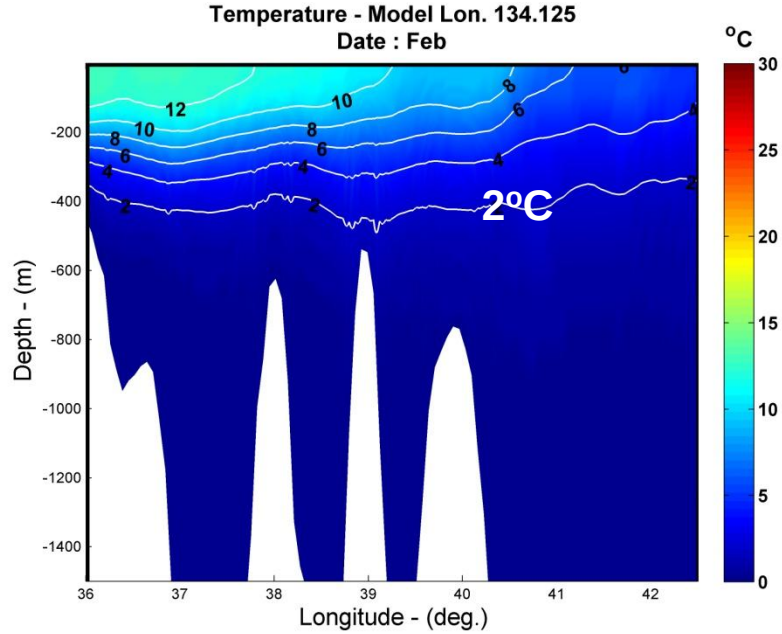
WOD09

Control Model (5 year mean)

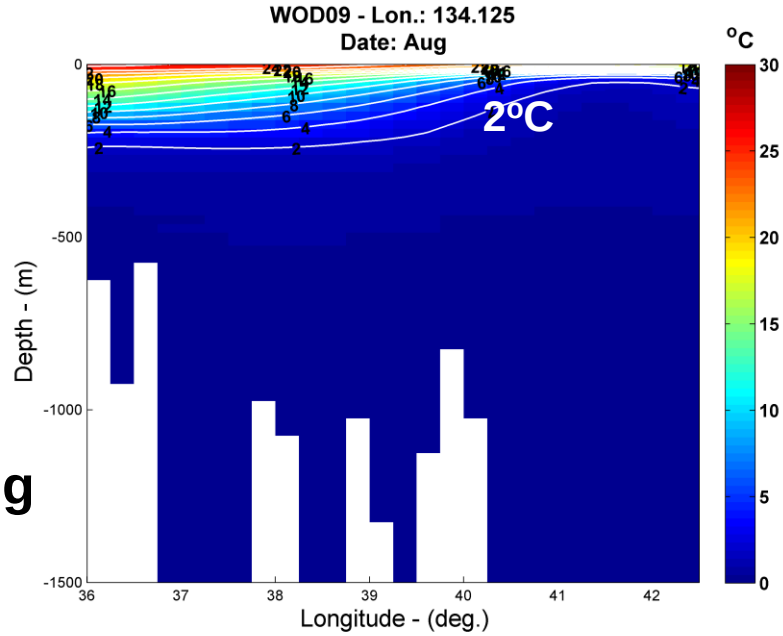
Temperature CI = 2ºC

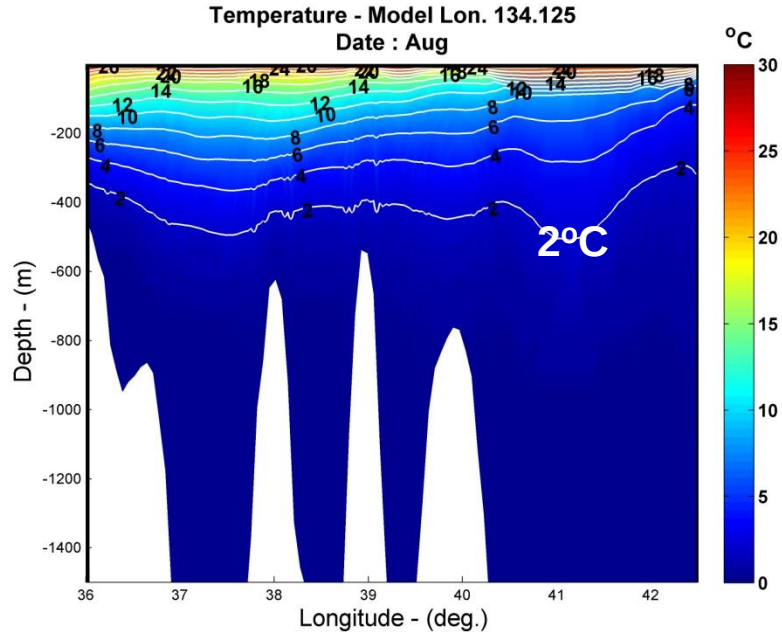
Feb





Aug





6. Summary

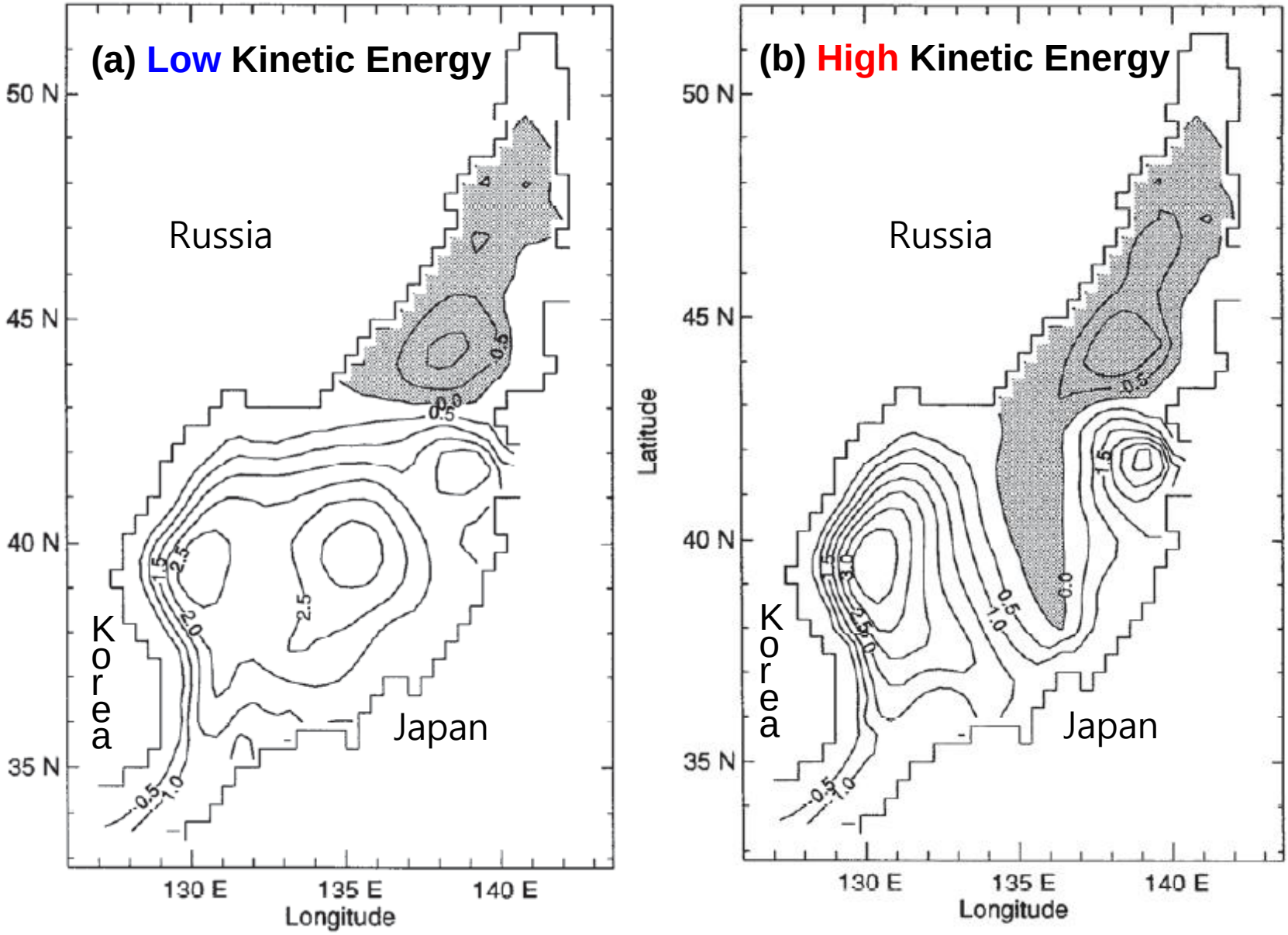
- Circulation of the Japan/East Sea was simulated from 2004 to 2008 and compared with the observation (satellite SST, SSH, and hydrographic data)

- Effects of atmospheric forcing, open boundary data, and internal low-frequency variability were examined
  1. ITV makes interannual variability of surface currents in the ***Yamato Basin*** *and the* ***Ulleung Basin***
  2. Interannual variations of open boundary data (OBC model) improved SST and SSH relative to those from mean seasonal forcing (ITV model). ATM model did not improved SST and SSH.
  3. *Interannual variations in the* ***Ulleung Basin*** *might be related to the interannul variations of OBC and ATM forcing*

Work in progress/Future work

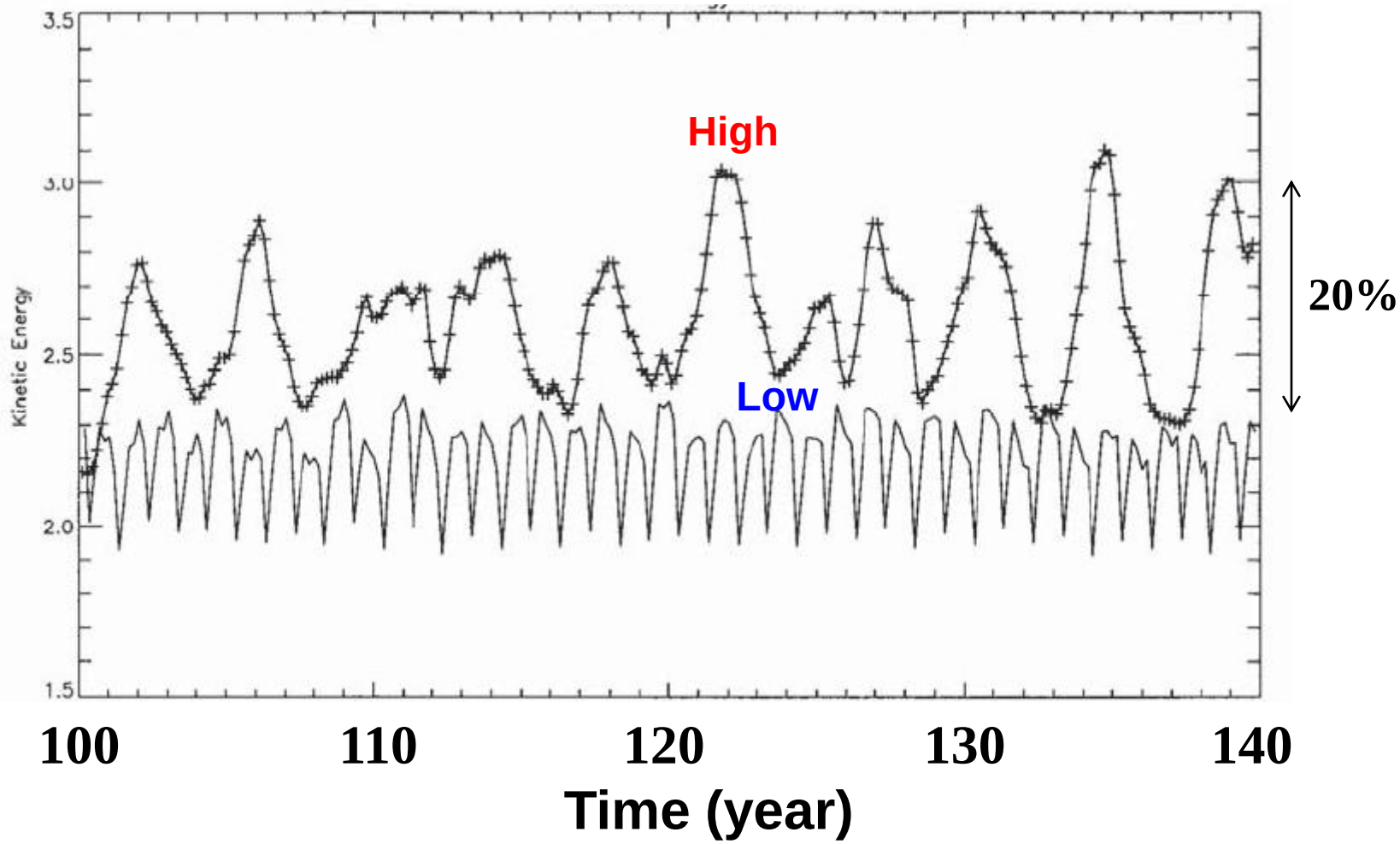
- Fix warm SST bias in the northern part of the JES during winter and improve intermediate water formation and cyclonic circulation in the northern JES
  - *horizontal viscosity*
  - *wind, air temperature*
  - *surface heat flux*
  - vertical mixing
- Extend the numerical simulation from 1991 to 2010 (20 years)
- Calculate quantitative contributions on the interannual variations from ITV, OBC, and ATM
- Dynamics: wind stress curl, vorticity, and instability
- Data assimilation and operational system

Thank you



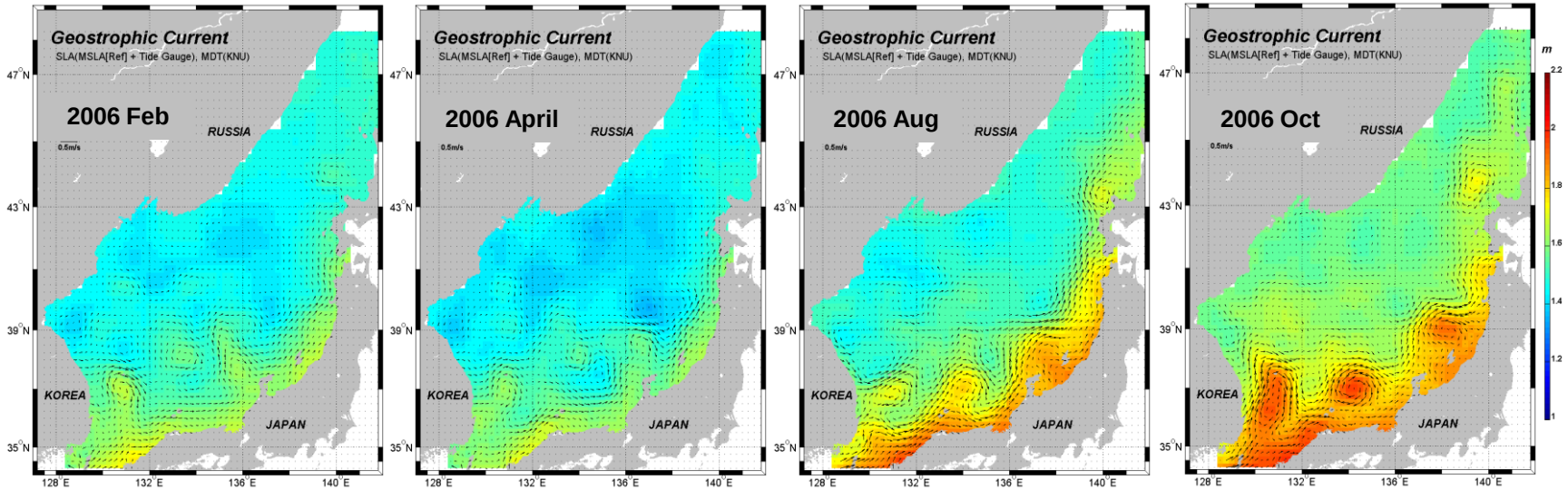
Steady forcing (Holloway et al., 1995)

Internal low-frequency Variability (ITV)



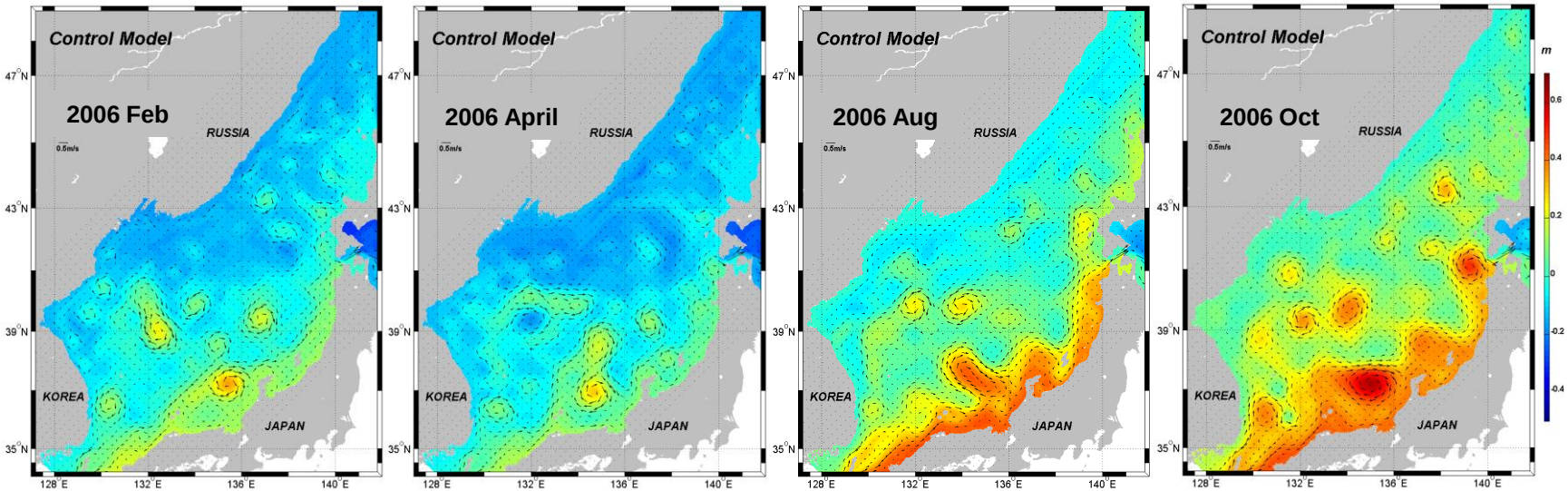
Steady forcing (marked +) and mean seasonal forcing (Holloway et al., 1995)

Satellite SSH



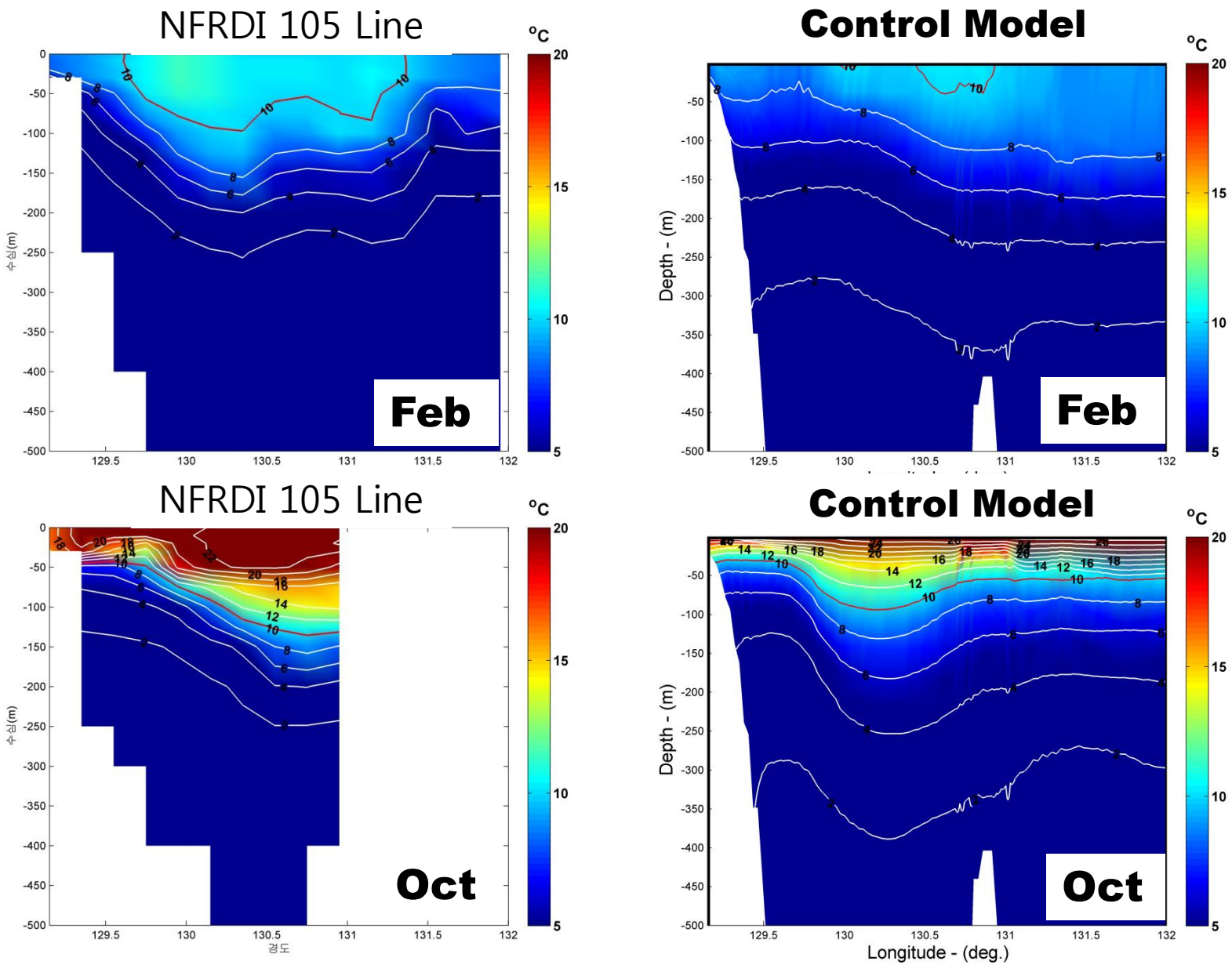
2006 Feb 2006 April 2006 Aug 2006 Oct

Control Model

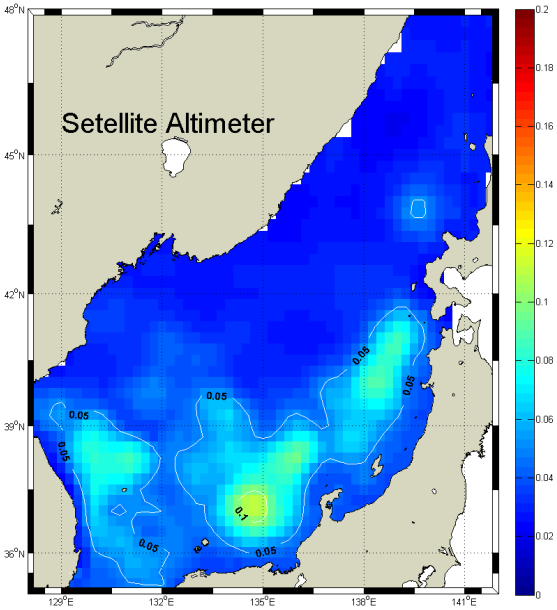


2006

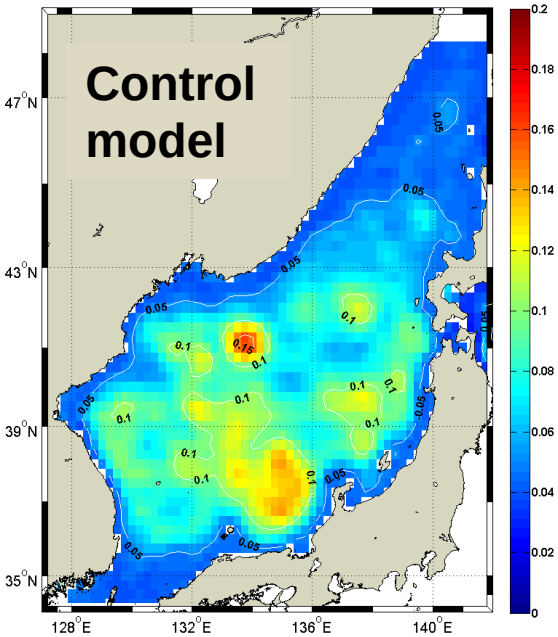
Temperature CI = 2ºC



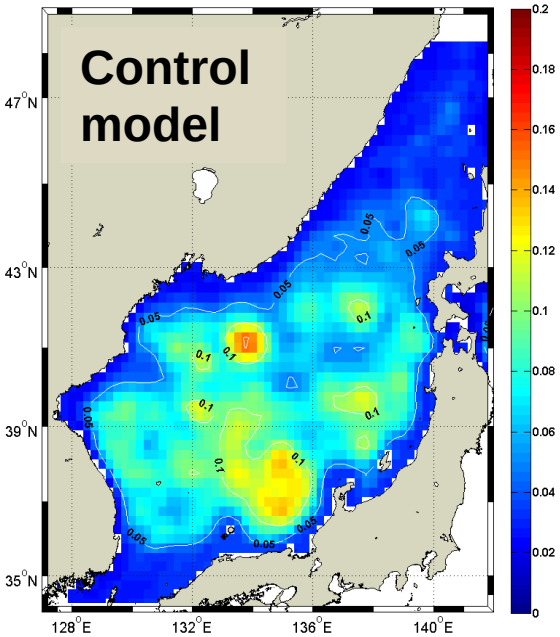
Nonseasonal SSH Variability (RMS)



Satellite altimeter data



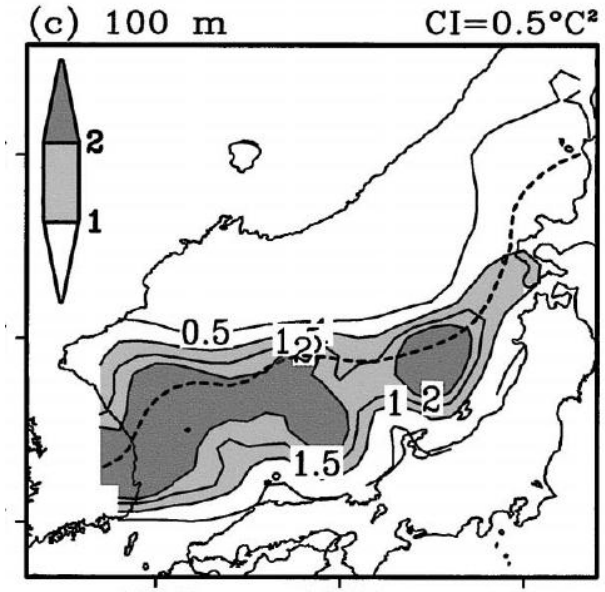
RMS of Daily mean SSH

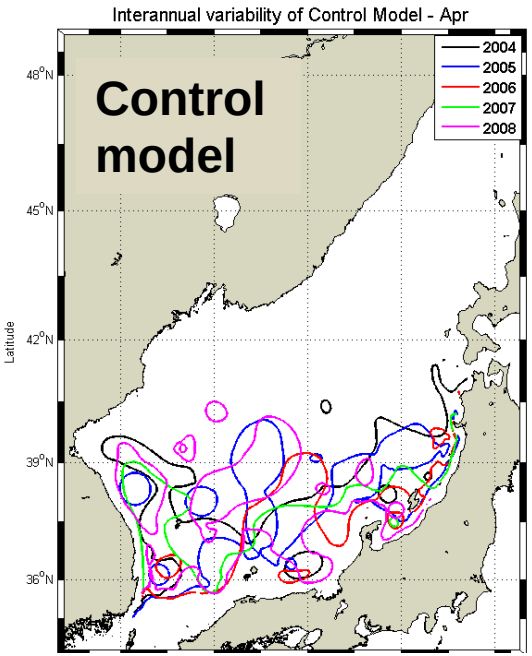


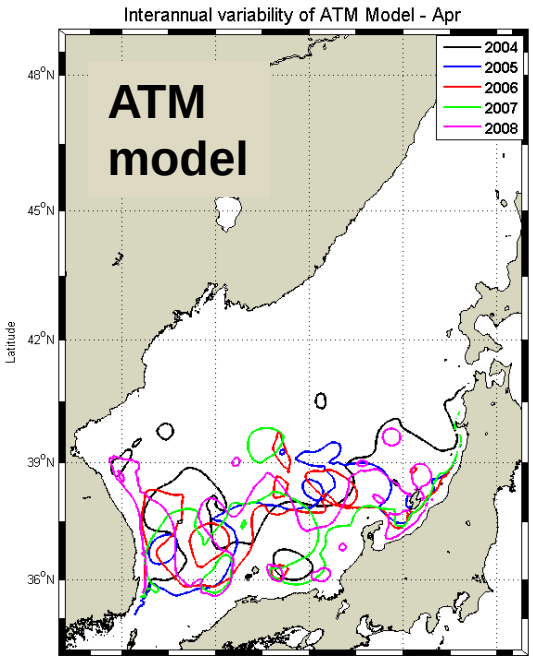
RMS of low-pass filtered SSH (6 weeks)

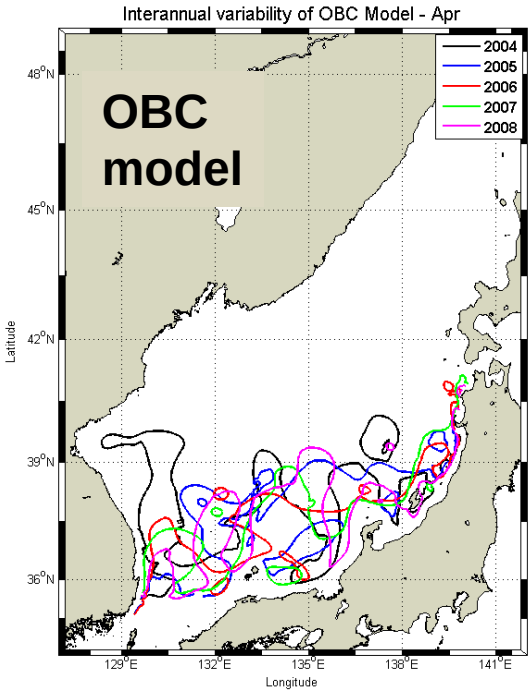
10°C isotherm at 100 m in April

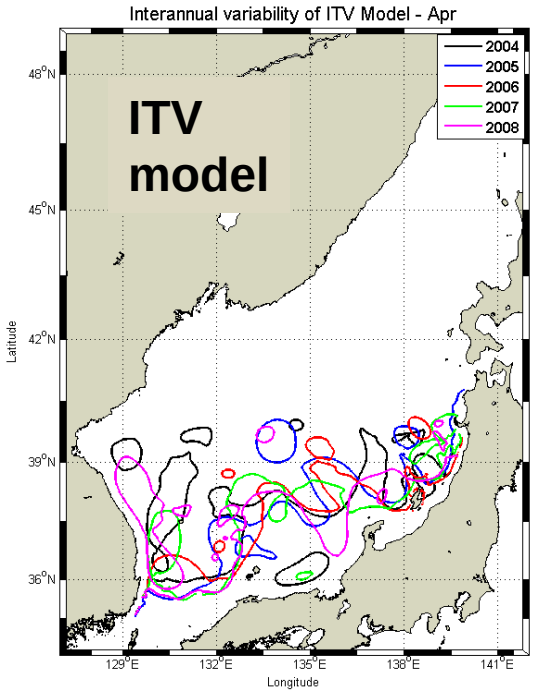
Temperature Variance
Minobe et al. (2004)





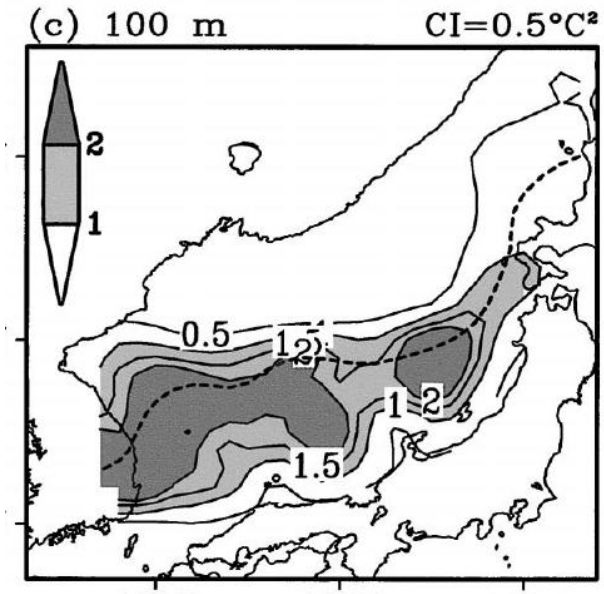


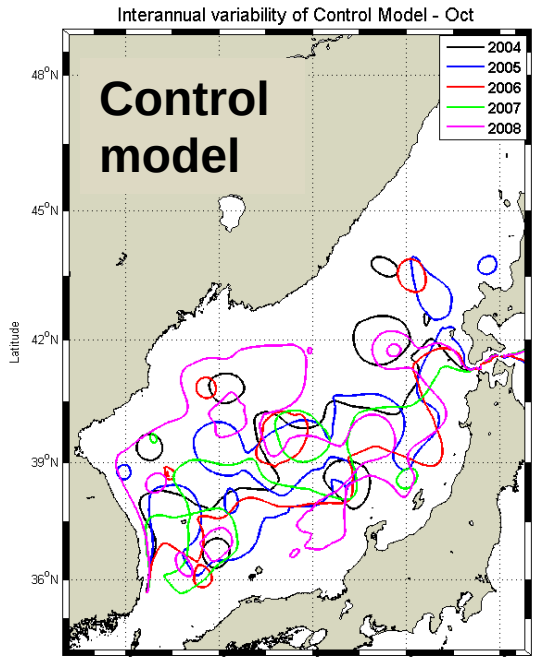


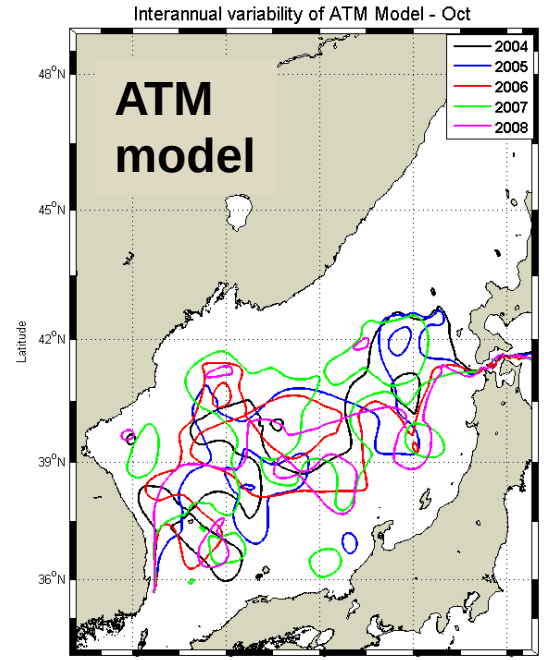


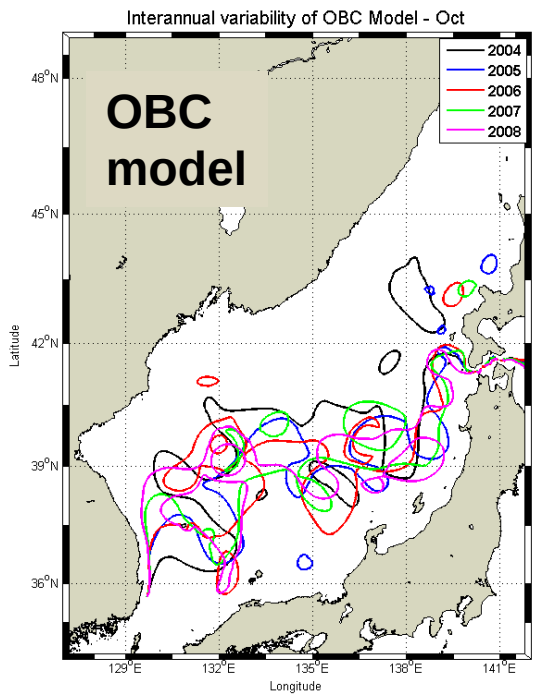
10°C isotherm at 100 m in October

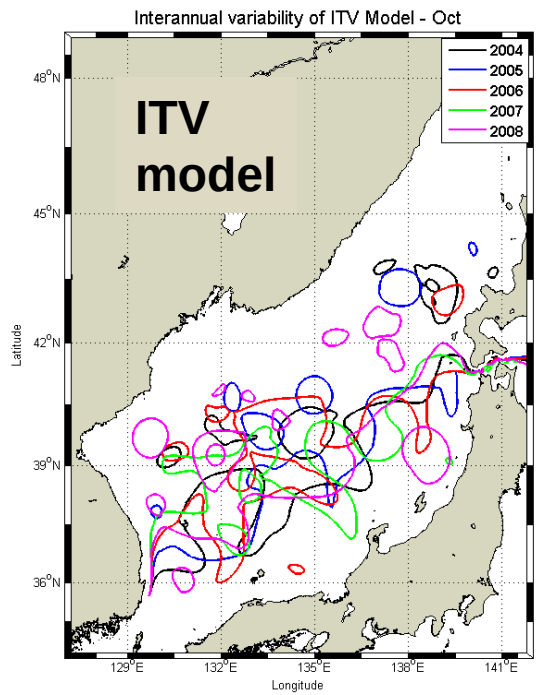
Temperature Variance
Minobe et al. (2004)



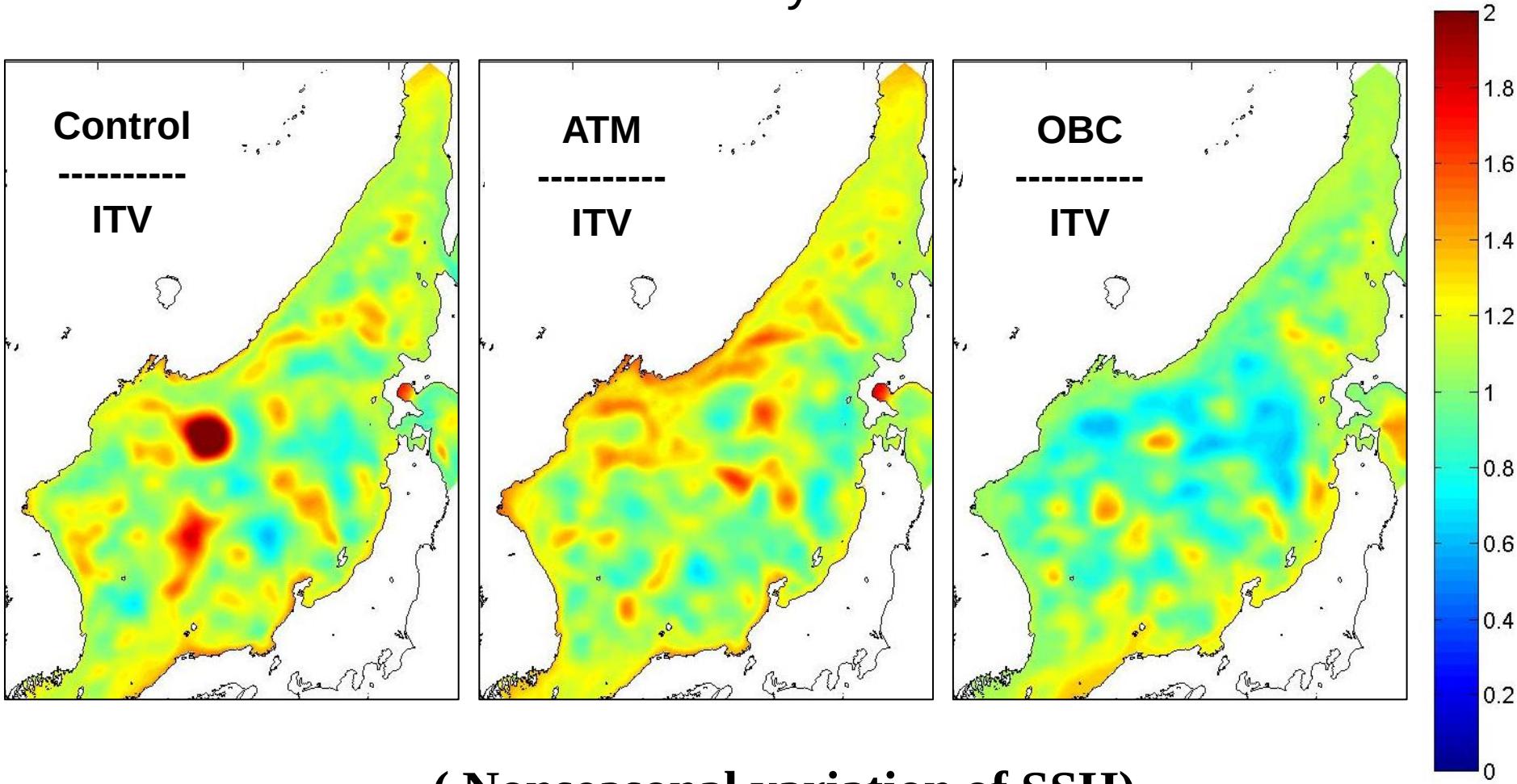








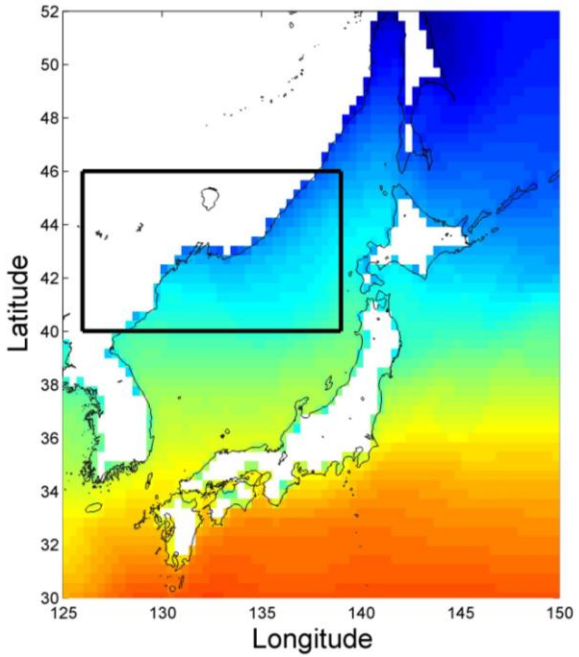
$$\text{Ratio} = \frac{\text{RMS of SSH anomaly from other model}}{\text{RMS of SSH anomaly from ITV model}}$$

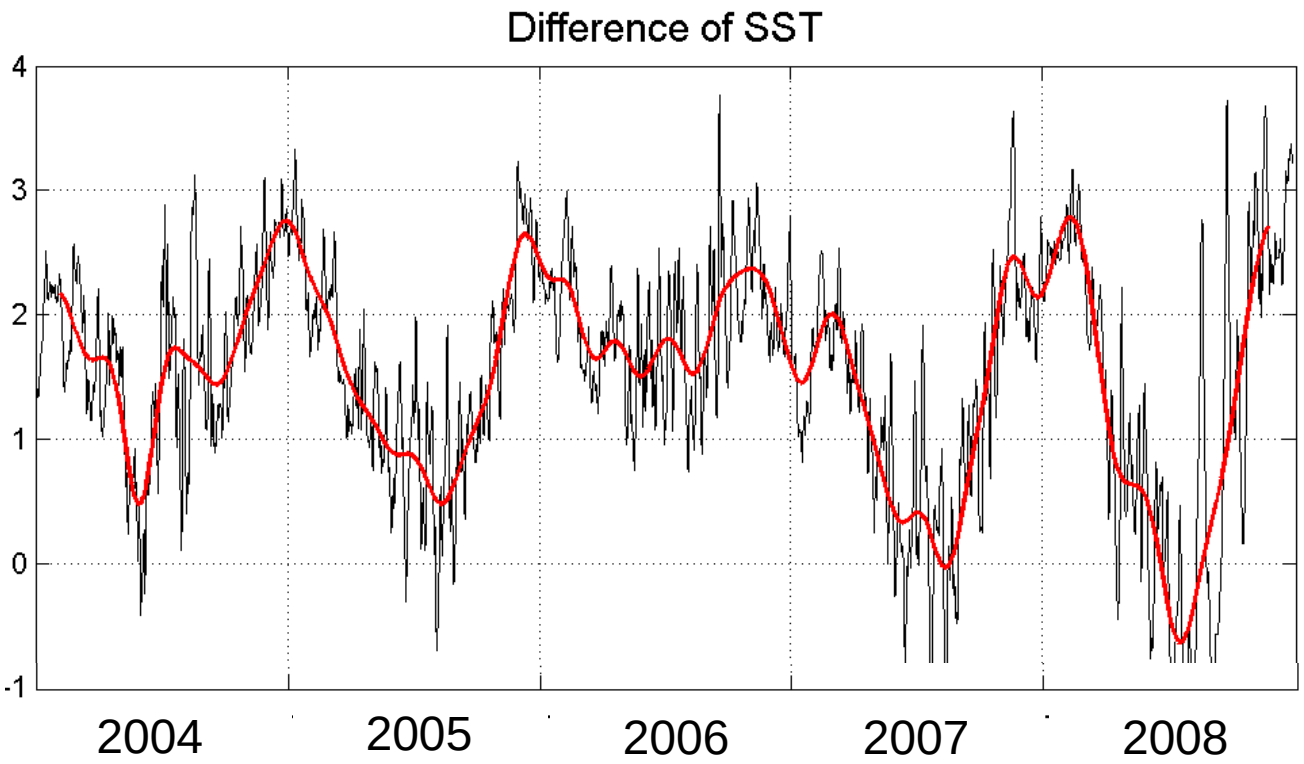


(Nonseasonal variation of SSH)

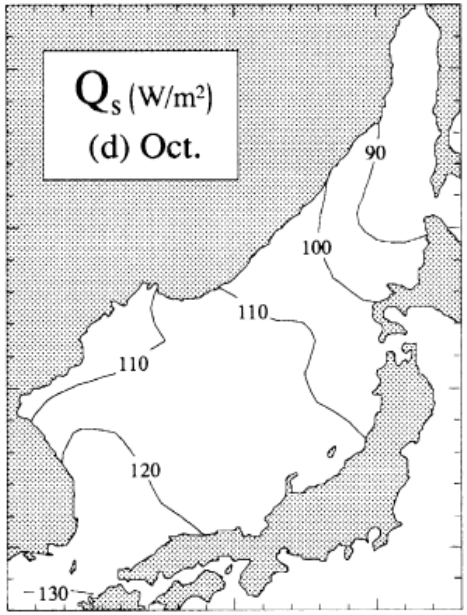
SST difference between model and observation in the northern part of the Japan/East Sea

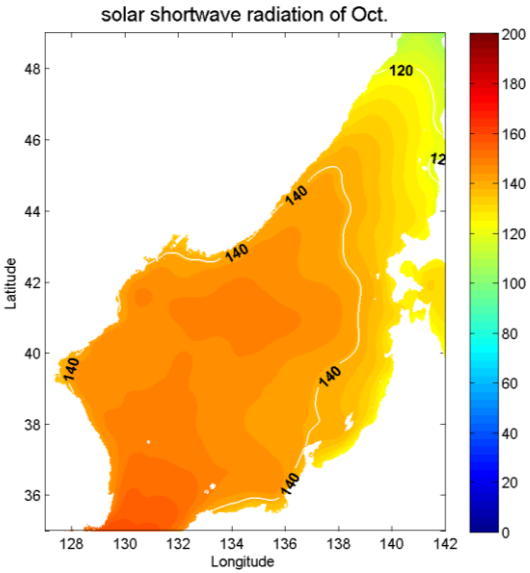
Model (1 m Temperature) – Observation (Satellite SST)





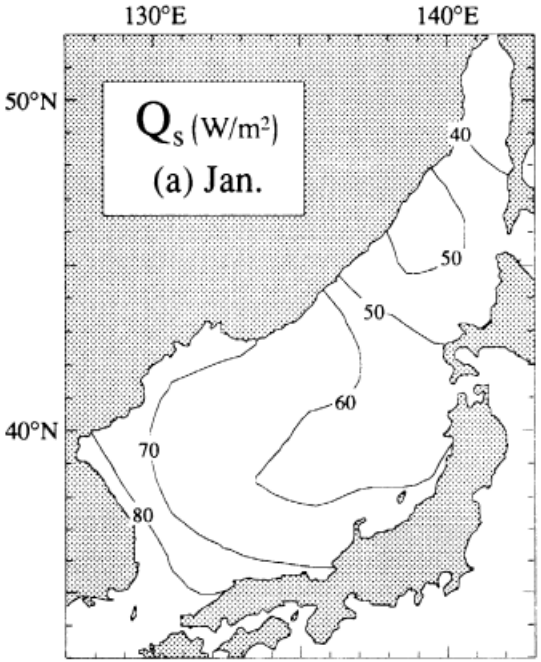
observation

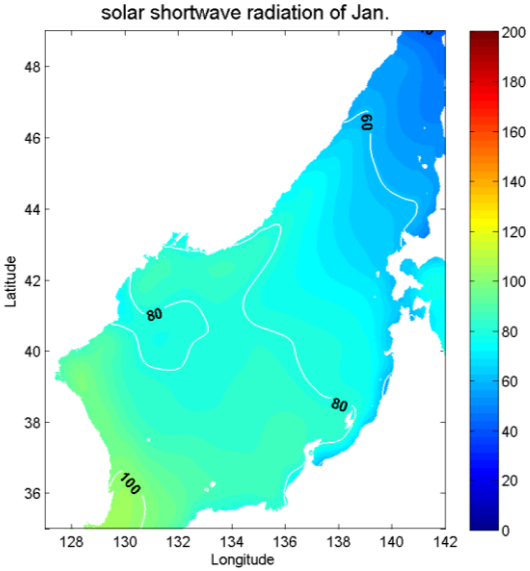




model

+30W/m^2





+20W/m^2

observation

model

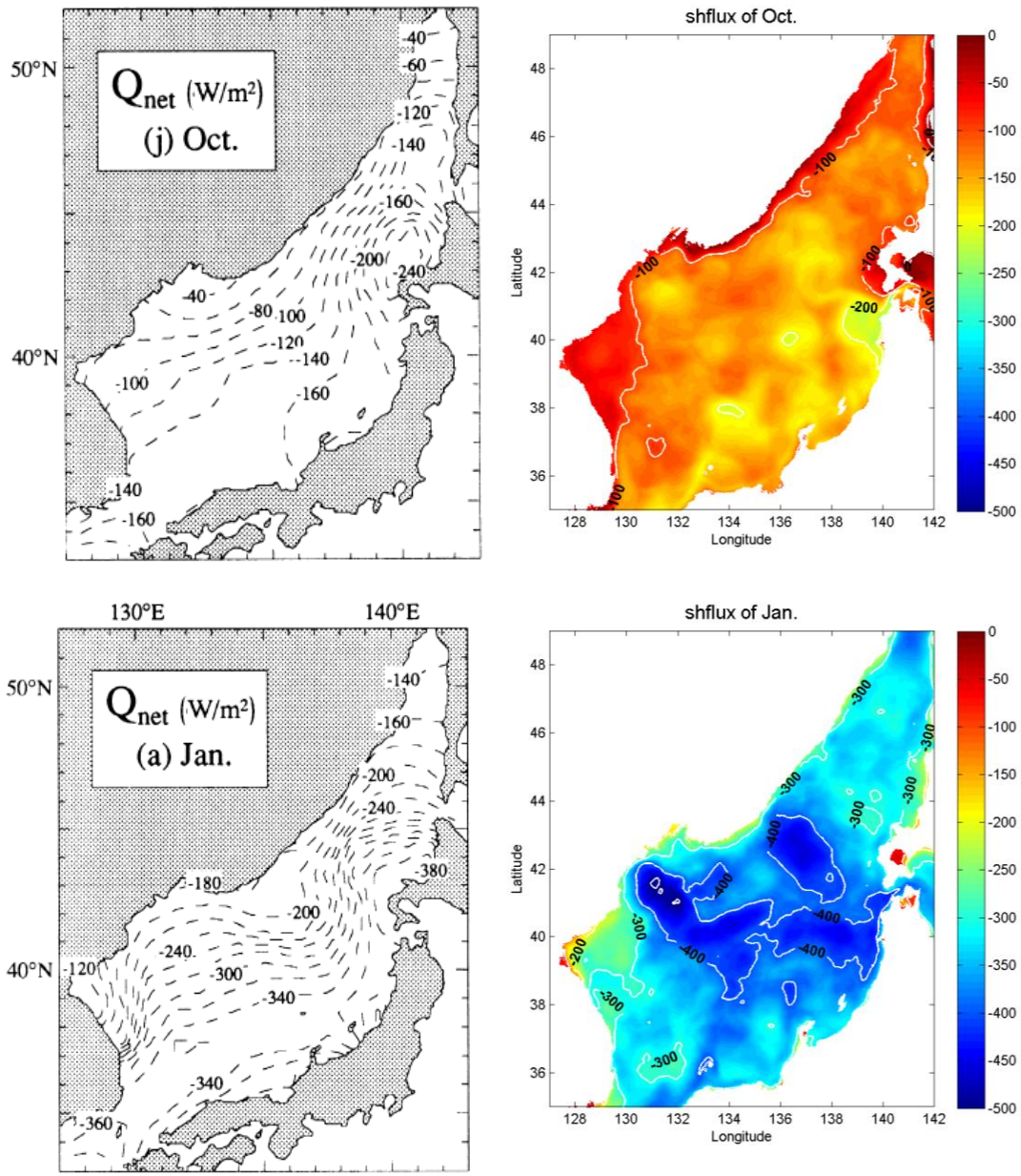


Fig. 10. Spatial distribution of the lc